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to pieces. This may often be done in the spirit of perfect honesty and to demonstrate the truth ; and, when so undertaken, the dissection of a publication—for it is no longer a mere pulling to pieces—is not the less severe because the operation is performed with urbanity ; indeed, when strict and not unfriendly truth is the dissecting instrument, and the subject-matter is *diseased*, the cut is frequently deepest.

I have therefore met the question, which I have set at issue, in its several branches, in its least favourable development, and have reviewed the subject under the light, which science and its acknowledged principles throw upon it ; testing that review by accepted data. I may have made mistakes, notwithstanding the long and deep study and attention, which I have bestowed upon this question ; particularly as the subject is new, and the arrangement therefore of its several ramifications, and the proportioning throughout of its machinery, have been no trifling undertaking ; but I do trust that nothing like an intentional error will be considered, by any candid reader, as apparent in the following pages :

At the same time let me not deceive any one. For about a period of twenty years, a soap-maker by position, and from peculiar circumstances, strictly a secret student of some branches of science, by choice, my pretensions must be as humble as my opportunities of acquiring the best, most available, and useful information were for a long period limited ; and it will not, I flatter myself, be expected by men of reflecting minds, that the terms of art will flow as freely in these sheets, or that the range of science—especially in those branches, to which it was not in my

midst of the most interesting portions of such works. In the present instance, to remedy this, as far as the case may admit of, I have separated much of this sort of description from the body of this pamphlet, and have preferred attaching a sort of tabular reference or index to the drawing, at the end of the book. For the same reason, I have there been rather more explanatory on the general nature, and some of the various parts of the invention, than is usual in a "Description of the Drawing;" so much so, I hope, as to have rendered it capable of furnishing, to many of my readers, a preliminary general idea of the principle here called into operation, and of its probable effects. Still, I have been very desirous throughout the pamphlet, to avoid an extreme minuteness of description wherever all was manifest, both as regards the machinery and its action—instances of which, are sometimes met with, that would be almost amusing, if time were no object whatever, and if attention could be given, long after the understanding was satisfied. The references however are more numerous than I anticipated on a subject so simple; but my first surprise at this was removed, when I considered what number of references would be requisite to describe the whole machinery of a locomotive, and what greater number must be added, if, not a locomotive only, but also a large portion of the whole working system of railway were, according to its present arrangement, and for the first time, to be brought before the public.

Still, I may have occasionally treated some portions of the general subject of this treatise, in a manner that may appear lengthy to several readers. My object has been to render the matter, where it was at all, clear. At any expense of labour to myself individually,

on which the public have expressed no opinion.

I gladly take this opportunity of offering my best acknowledgments to those gentlemen who have kindly favoured me with suggestions and advice on the several occasions, on which I have availed myself of their friendly offices in the following pages.

2, Tiverton Street, Ardwick Toll Bar, Manchester,
June 25, 1842.



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and economize the means of the human race, is generally tantamount to promoting material comfort, domestic happiness, and social enjoyment; it is often, the same thing as to remove the pressure of contracted circumstances, to give buoyancy to the mind and to restore vigour to the human frame. Objects such as these, constitute the best claims of science on public support and general esteem.

The grand achievement of late years, in mechanical science, has been the establishment of railways. These, with their wonderful machinery and general economy, engross no small share of the attention of the whole of the public, from its lowest members up to "Home Secretaries," both in Europe and America. Another quarter of the globe is likely soon to feel their influence; and railways must shortly become most interesting subjects of enquiry, as respects the prospects they may offer for the advantageous investment of capital—embracing necessarily the modes and opportunities for their construction and practical arrangement—in India, if not also in other parts of Asia.

It would be trite then to say that railways are concerns of national importance. No one disputes it; their results would negative such an assertion. Their share market claims its place in the public journals, by the side of the stock market:

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great advantage from the proximity of a railway, in the swift conveyance it offers him, for the produce of his farm to market.

Railways therefore in their effects as at present developed, may, without the slightest exaggeration, be said to be wonderful; and in the development of their future effects, they are already working a change in the whole framework of society, peaceable and without strife, which in a comparatively short space of time, is likely to exhibit to the world, consequences of a magnitude greater than those which have arisen from revolutionary convulsions, the march of victorious armies and the longest wars; and in most respects of a character, very opposite to that of the results, which such epochs in history have afforded. Napoleon himself pointed to a road (the Simplon) as the most lasting and trustworthy monument of his glory: little did he imagine, that even his great work must sink into comparative insignificance before the labours of a few years' continuance, of English engineers—without considering the great railway works on the continent and in America—when supported in their stupendous undertakings by the countenance of the British public, and aided by the powerful lever of British capital.

When these effects are borne in mind, and when it is recollected that, where we travelled at the rate of ten miles an hour—

which, fifteen years since, was considered a maximum exertion—we now *glide* over the country at a speed of twenty miles, or more; and when it is remembered that places, which, as regards the public at large, were considered so remote as to be seldom or never visited, unless the emergency of the occasion rendered such an effort indispensable, are now “run down” to, in a few hours, as being merely a morning’s trip; and when also the tradesman recollects that he can now have his goods down in the country in a few hours, which on the old system, required several days in transit; it will not appear extraordinary that the wonder of the public at this great change, should for a time have so far absorbed its clear powers of reflection, as to render it nearly indifferent to the question as to whether its first expectations of the benefits to accrue from this extraordinary feature of our times, had been altogether realized; and whether improvements, every way advantageous, could not yet be introduced into the system of locomotion. But it appears the period is arrived when enquiry is beginning to resume its wonted energy; and questions are now exchanged every day among the community at large and in the public prints, indicative of doubt whether the locomotive system has at once started into existence in a state of absolute perfection, and, unlike every other invention which the world ever witnessed, incapable, at least in its leading features, of all improvement. It was anticipated, not that time only would be saved, but also that the expense of transmission either of goods or individuals, would be considerably reduced by steam-locomotion, in which iron supplies the place of horses, and coal, the place of hay and corn; but the enormous annual cost of “maintenance of the way,” including the whole locomotive department, has, for the present, set that question at rest. It was expected that this mode of travelling would be exempt from frightful casualties; and “railway accidents” now occupy a conspicuous place in the columns of every weekly journal. It was greatly hoped—almost promised—that this system would extend its arms right and left, till it reached into every town and populous locality; but the public were at length informed, better experience had demonstrated, that these “Branches,” if established at all, must be undertaken by each separate town, and that the good burgesses, to accomplish such desirable object

and will be considered with the care and attention due to proposals, which, if founded on correct data, embrace in their principles, much public benefit, and, as respects railway shareholders in particular, great individual advantage and profit.

The author begs to state, that he has submitted his invention to the first scientific and engineering characters, with whom he has the pleasure of being acquainted, and, though solicited to point out any objection to the working of his system, if any such were apparent, nothing of such a nature has presented itself to the minds of any of these gentlemen; indeed, the answer has frequently been, that the system appeared so reasonable in drawing and description, that it was now advanced into that position, which called for its merits being brought to the test and decision of a full practical trial. Though something, partly of this nature has been already alluded to in the preface, it seems not improper to repeat this here; for hydraulics is a science which has been less popular and less studied than several others; hence, its capabilities may not at first, and until they have been a little enlarged upon, be so fully appreciated by some of my readers, as they deserve. But the powerful agencies which this leading branch of hydronymics commands, offer it, particularly in its wider ranges and more active energies, as a subject well worthy of attention. Its greatest capabilities have been much over-

powers and capabilities to work well for mankind;* but it is to be hoped that most of the mist which may still hang around some of its nobler proportions, will be shortly cleared away; for attention has been drawn to this subject from a quarter well deserving of respect and notice.†

In the meantime, fully sufficient has been done in this science to elucidate, for all practical purposes, the subject I am now to treat, and upon which I shall be particular to make myself clear in the following sheets; after the perusal of which, it will remain for my readers to decide whether this application of hydrostatic propulsion does, or does not hold out strong and reasonable promise of its capabilities to move forward our railway system another step in its extraordinary career,—probably scarcely less efficient, as regards simplicity and power, and generally as little anticipated by the public at large, as was its former advance by locomotive engines, prior to the opening of the Manchester and Liverpool Railway. I will now, therefore—avoiding technical

* See Note A.


† Rev. William Whewell, who, in his "History of the Inductive Sciences," and in the chapter on "The Discovery of the Mechanical Principles of Fluids," remarks, "Even up to the present time mathematicians have not been able to reduce problems concerning the motion of fluids to mathematical principles and calculation, without introducing some steps of this arbitrary kind."

ply of water, placed under the condensed atmospheric pressure of an air vessel;—the first acting medium in this latter case, I would here remark, may, as convenience and opportunities offer, be either a barker's mill, a water wheel, a steam engine, or an hydraulic engine of that peculiar and effective construction which, as far as cylinder, piston, valves, and reciprocating action are concerned, assumes the features of a steam engine. But, having said thus much for the satisfaction of my scientific readers, it will be better to postpone all explanation of the mode in which the agency and power of such media may be rendered active and economically available for this system of propulsion, till we get further into the subject.

The effective pressure exhibited by water in pipes, is, in fact, familiar almost to every one. Who has not, in the days of his childhood, if residing in a town, amused himself by pressing his finger firmly upon the mouth of the diminutive pipe, which supplied his home, from the neighbouring "main" of some water works' company, with water, and who has not remarked the pressure requisite to restrain even a stream so very small? But, probably, the juvenile observations of many have been satisfied with these facts, and have not prompted those inquiries which might have procured for such young observers the information, that these little pipes, whose gush of water so much surprised them, are frequently "throttled" by a brass ring being

dreadful eruptions, while constructing, in the names tunnel, &c., or whether they reflect on the operations of this pressure, on a far more widely extended scale, in the phenomena of nature; where this power removes hills, uplifts districts, or, when withdrawn, allows them to sink; loosens and throws down the heads of deep cuttings on railways, projects the noblest natural fountains, inundates mines; and, in its more active state, with the aid of its momentum, lifts masses of rock from the beds of torrents, and hurls them into other localities. It has even, as geologists affirm, heaved these huge fragments of an antediluvian world from the bosoms of valleys, or torn them from the mountains, and, carrying them over countries, kingdoms, and seas, has eventually deposited them on spots, hundreds of miles remote from rocks of all kindred character.

And, to address myself again to general and popular observation, and to what is every day to be witnessed, as a familiar instance of the effect of hydraulic action, I need only mention the common lifting or pumping steam engine with its hydraulic machinery. The term steam engine is synonymous with power; and the effects of this term and its realization in practice, are to be witnessed all over the United Kingdom, and in every part of the high seas. This power has raised the population of Manchester from some thirty or forty thousands to upwards of three



not fracture, the ponderous, but well-proportioned machinery, even of the steam engine itself!

Still, under able engineers, all these apparent elements of discord are so well equalized into harmony, that the steam engine forcing or lifting pump, is everywhere to be found contributing greatly, in one of its most ordinary positions, to the comfort of the population of London, and many other of our towns; where it becomes the medium for supplying their inhabitants with wholesome water. I mention this, more clearly, to bring before the minds of my general readers, the power of my propulsive medium; not to convey to any one the idea that I shall apply that medium with a reciprocating action up my propulsive piping; far otherwise; for the power of the rush of the water, or, in other words, its momentum, will be entirely unchecked by any reciprocation, and all in the direction in which I require it to propel the piston, and, through that, the train.

It is true, I shall occasionally apply the steam engine forcing pump as a *first medium* for conveying propulsive power to the water. That is, where natural heads of water of sufficient elevation, or smaller falls to work hydraulic machinery, are not, by the aid of piping, within convenient reach. The question of the distance from which water might be conveyed, to furnish supplies to reservoirs, under adequate pressure, to feed the propulsive pipes, is less material, than the question of amount of

the same conditions, consume 10 to 12 lbs. or even more; and other stationary engines, of the ordinary construction, are esteemed very successful mechanism, whenever they can bring down their average consumption of coal to 8 lbs. per horse power per hour.

The duty obtained from the Cornish engines is *now* undoubtedly very great; but what would it become, should the "pliable solid," as water has been aptly termed, which they have to lift, be eventually as completely subdued by engineering skill and perseverance, into perfect and immediate tractability, as the prodigious force and rush of steam is at the present moment in the steam engine itself.

This is not to be considered very hypothetical. What is now more common than the high-pressure engine? How could the locomotive be worked on any other principle? How could the Cornish engines perform their present amount of duty without it? And yet, Mr. Watt, himself, in early life, after testing this principle by experiment, pronounced it to be impracticable; though he lived to see the time, when this was proved to be a mistaken conclusion, and when he availed himself of what further experience had manifested. After so much has been accomplished in steam, particularly in the case of the Cornish engines, it would be rather hazardous to affirm that the water with which



stituted, as respects the amount of its effects, and the difference between a free natural flow of water and an intermitting stream, will, in the two cases, hold good, when the circumstances are borne in mind, to a sufficient extent to justify its being adduced in illustration of the idea now advanced.

A material characteristic of liquids, is their disposition to acquire a true horizontal level. The first use they make of the facility of motion by which they are distinguished, is to exert it in regaining this level, whenever it has, from any cause, been disturbed. It matters not whether a torrent has precipitated itself down the face of a mountain, or a river poured itself into one side of a lake, or whether one end of a tube full of water, has been bent upwards, or whatever else may have occasioned the disturbance of the water-level; that level, if the liquid be left to itself, will be regained, and the more speedily regained, in exact proportion to the extent or height of the disturbing cause. Distance cannot neutralize this law of hydrostatics. Whether the surface or horizontal column, whose level has, at one side been disturbed, be ten yards, ten miles, or any other measure in length, the liquid immediately begins to exert the power of motion, inherent in it, under such circumstances, to regain its true horizontal level; and it never will be in an absolute state of rest, until that is accomplished.

I have already alluded to the fact, that the water-works of

an infraction of the law of gravity, and the liquid, if not impeded, rushes forward, under influence of that power, to restore to force, its interrupted law.

Some large towns however, which are favourably situated in hilly districts for the purpose, obtain their supply of water from the immediate action of this law of hydrostatics, which impels all liquids to seek the lowest level presented to them. These places present fine examples of this law in wide operation. They have their supply-dams placed among the hills, sometimes at a distance of several miles, at a sufficient elevation above the highest part of the town ; and the water being conducted down to the town, by large pipes or mains, is there distributed, as occasion may require, in every direction, whether high or low ; provided only, that the point of supply be at a level somewhat lower than that of the supply-dams or reservoirs.

The water or spirit level, which is usually attached to our barometers, in order to act as a guide to hang them in a true perpendicular line, is a familiar instance of the action of the same law, on a very small scale ; and a similar spirit level is, on account of its extreme truth and accuracy, an indispensable appendage to some of the surveying instruments, used by our civil engineers, as well as to certain philosophical apparatus.

I have been thus particular, in the latter part of this intro-

dering upon prolixity, it should be remembered, this has been done under the impression, that hydraulics is a science, which, particularly in its wider ranges, has not yet received that share of public attention, to which its importance entitles it. I may also add, that the necessity of rendering the whole subject, to which I now invite attention, as generally intelligible as possible, has been strongly urged upon me, from a judicious and experienced quarter.*

* See note B.

will travel, through the medium of connecting horizontal piping, when acting as a propulsive agent, for railway purposes.

These two questions will require very careful consideration, in order to put a numerous and respectable portion of the public, who may not probably, heretofore, have given attention to such subjects, sufficiently in possession of the scientific principles which these questions involve, to enable such individuals, in common with others, to form a general estimate of the practical results, which these investigations promise.

The first question is one of very easy solution, if understood as being proposed under its most simple conditions. Thus, the pressure and propulsive power, at the foot of any vertical column of water, of one even bore throughout, will, upon proper means being taken to apply it, be found to be identical with the weight of the water contained in that vertical column; and which liquid is, at the foot of it, pressing downwards, with its whole weight, there to escape. For instance, I propose to make my propulsion piping one foot in diameter; and I should wish, in all ordinary circumstances, to place such piping under a pressure (vertical or otherwise,) at first, equivalent to six free atmosphere. Now, as a vertical column of water, 33 feet high, is considered a counter-

... be accomplished, at the rate of 220 feet a minute, or two miles and a half an hour, which is considered the average steam engine speed. If the work is done twice as fast, twice the effort has been made; and accordingly the power which has accomplished this, is properly and accurately considered, twice as great as in the former supposition. In the same way; if the power have accomplished its work in a third, or a fourth part of the time, it is estimated as being three or four times as great in amount, and so on. When I proceed, as I shall do immediately, to the consideration of the second question proposed at the commencement of this chapter, and on which the subject already touches, I shall have to show the natural rate, speed, or velocity of fall, of such a head of water, and in such piping as I have just described. It will be found that the acceleration of speed and consequent multiplication of power, under the given circumstances, will be very greatly in favour of this mode of propulsion.

The above effect being borne in mind, will prove of great importance in hydraulic propulsion, in the way of correcting any error in calculating the amount of the power of this first active

* "Now as the air's pressure near the earth, by several undeniable experiments, may be proved at least to be equal to the absolute weight of thirty-three feet of water, it will at all times counterbalance, and, therefore, raise and sustain that quantity."—*Clare's Motion of Fluids*. Page 46.

its investigation, much of the practical or working effect of hydraulic propulsion.

One of the first laws in mechanics informs us that a body, whether fluid or solid, falling *freely* through space, accomplishes, in equal times, distances, which are, relatively to each other, *as the odd numbers*: that is, a body is found to fall 16 feet, (or to approach nearer to mathematical accuracy, we should say 16 ft. 1 in.) in the first second; it will, in the next second, fall through three times that distance; in the third second, through five times; and in the fourth, through seven times the same distance, and so on. We also know that the distance fallen through, in any interval of time, *is as the squares of the times*; and that, in two seconds, it will have fallen through 16 ft. $\times 4$; in three seconds, 16×9 ; in four seconds, 16×16 , &c. Also, though a body falls through 16 feet in the first second; yet, at the *end* of that second, it is falling at the rate of 32 feet; and this being kept in mind, we know that the rate or speed of descent, is *as the times*, and that, at the end of every subsequent equal interval, it will be falling at the rate of 32 feet, multiplied by the times, or number of seconds, through which its descent has been continued; at the end of the second second, its rate of descent, at that moment, will be 32×2 , at the end of the third second, 32×3 , and so on.

also might be quoted to the same effect. This may be observed in a portion, in italics, of the passage I have extracted from him, at the end of this pamphlet, as being, in his rather quaint language, beautifully illustrative of some peculiarities in the vertical fall of water, as well as of other bodies.* One of the authors of Tredgold's Tracts, (Venturé) also hazards the same assertion, stating that "The fluid stratum, continuing to descend through L C (a cylindrical tube) *tends to accelerate its motion according to the laws of gravitation*"—(page 139, second edition.) This, I am afraid, is one of those instances in which he entitles himself to the observation which Tredgold makes in his preface, on the inferiority of his judgment, and which remark, of the very able editor, I have already transcribed in Note A.

In that note also, there is abundant confirmation in the well-merited eulogy it bestows on Dr. Young's work, of the great security of the basis on which I place myself when I accept the formula, which Tredgold derives from Dr. Young's Summary of Eytelwein's Hydraulics—in rejection of more favourable principles, which the preceding quotations would seem to authorize—as the foundation of my calculations in the following pages. This rule or formula does not show that water in vertical piping, falls exactly according to the laws of gravitation, or with the whole velocity due to them; and for this sufficient reason, that

* See Note C.

retarded, the fluid which is next adjoining it, in the moving column, must to a certain extent feel the effects of the contiguous retardation. This is one cause of friction: and there is another, which arises from fluids having a tendency to form eddies, in their passage through pipes, or other channels. The smallest obstruction in the pipes intercepts the free course of a certain portion of the fluid, while the fluid itself, in passing over this portion, turns it round and round, and either drags it away from the cause of interception, for other eddies to be formed there; or, if not sufficiently powerful to do this, maintains in it a velocity of revolution, which in a manner condenses and forms the obstructed and obstructing fluid, into the shape and character of a revolving cylinder; and it will then impede the free passage of the descending column exactly in proportion as its bulk—or, to speak more accurately—as its section is to that of the fluid which is passing over it. Now, though on account of their springing or rebounding tendency, elastic fluids will have the greater disposition to form eddies, yet, it must be admitted, that the eddies of non-elastic fluids will, though smaller, be more solid; they are, however, well defined and incapable, at first, of a whirl, and afterwards of a gradually condensing or compressing, and wrapping up within their vortex, of more volume, as may occur in the case of elastic fluids; and, in vertical piping,


D

pages back. Now this tendency to a vacuum is beautifully counteracted by the pressure of the air, which at the top of the column, acting on the head of the water, forces it down the pipe with a velocity greater than what is there due to it from gravity, to fill up what would otherwise be vacuity. At the bottom of the column, the same pressure of the air becomes of opposite effect; and there meeting the force of the discharging water, partially obstructs its free egress, and allows the water towards the top of the pipe—with the aid of its own air-pressure—thus to maintain with the rest of the descending column, one well connected stream. Thus the pressure of the air divides its effect in preventing a vacuum in the pipe, equally between the top and bottom of the descending column of water; thus too, from its partially obstructive pressure on the bottom of the column, it detracts something from the velocity due, by the laws of gravitation to the descent of a vertical column of water through piping.

Ample deduction from the velocity of water in piping, for the retardation due to the above causes, as well as that due to the liquid in its passage up horizontal pipes, is made in the formula or rule in Tredgold's Tracts on Hydraulics, which I have promised to bring under the notice of the reader.*

* See Note D.

ing pressure on the propulsion column of water, as near as possible to those pressures, which are to be found in practical application among the great lifting or pumping engines. Not having at hand the exact length of the lifts of water in the great mines in Cornwall—which, however, must be considerable, as some of the mines are 500 yards, or more, in depth—I find by the printed description of an engine, constructed on the Cornish principle, by the eminent engineer, William Fairbairn, Esq., to drain a mine 720 feet deep, at Verviers, in Belgium, that two of the lifts, or rather lengths of pipe, are 180 feet each, the water, in both cases, being forced up by a plunger or ram. The pressures also to which some of the water works' companies subject their pipes, are occasionally very high. Even in this town (Manchester) in the midst of a comparatively flat district, the water works company's pipes are worked under a pressure of 140 feet ($4\frac{1}{2}$ atmospheres), and when of from 12 to 18 inches bore, and $\frac{3}{8}$ of an inch in thickness, are warranted to stand a pressure of 300 feet, to which they are proved; and I am assured, from sufficient authority, they would bear a great deal more. It will therefore be quite within reasonable limits to place the propulsion pipes for this system, under six free atmospheres at the commencement of every section of piping, and under five at the end of it. I shall occasionally require half an atmosphere extra, though not in the



give that amount of supply of water, which will furnish the decreased velocity, or nearly that, due to the further end of the pipe, when the retardation has been taken into calculation. The communication valve to effect the above purpose, is first acted upon by the pulley, as shown in the drawing, which, on being lifted by the inclined plane attached to the travelling truck, raises the valve about one-third : after this, the remainder of the opening is effected gradually by a little machinery, I also show in the drawing ; it is done in such manner, as to preserve, in the propulsion column of water, through its whole course up the pipe, one equable velocity ; and which clearly must be the same as the final velocity ; thus, as the velocity first allowed to the water, in its progress up the pipe, tends to abate, this again tends to increase it, so as to preserve in it one unvarying speed throughout the whole of the pipe, now under consideration. This action of the communication valve illustrates one of the most beautiful laws in hydrostatics, and which is usually exemplified by the hydraulic press or by the hydrostatic bellows. These instruments show, that by contracting the upright pipe (in the case of the bellows, for instance), and thus reducing the supply of water, you reduce the speed or the quickness with which the instrument acts—for the speed is under complete control—but by doing so, *you nowise do, or can reduce the available pressure, and lifting power of the water* : that, under all circumstances,

I have now given the rate, and in the following chapter explained the nature of the final velocity, which must previously be well understood. The consideration of the amount of propulsive power due to this system, under different conditions, can then be resumed with every opportunity of arriving at a clear and satisfactory conclusion; and this, it will be remembered, constituted the first question, proposed at the commencement of the present chapter.

We now, therefore, require the final velocity of a horizontal column of water, namely that due at the further extremity of each section of propulsion pipe; or in other words, at the mouth of a pipe one foot in diameter, and distant 70 yards horizontal, from the power head. It should always be borne in mind, that, though the initial velocity is obtained under a pressure of six atmospheres, the final velocity must claim the impulsive effect of five only. Under all the conditions now mentioned, this final velocity will be found to be equal to a speed of $27\frac{1}{2}$ miles per hour.

Before I proceed, I will recapitulate the preceding results. I will also insert a few more data, as this may save the delay and trouble in working out the figures, if they should be wanted for purposes of comparison.

Water as a propulsive agent, under a pressure of six atmospheres, and in tubing of one foot diameter, furnishes;

No. 1	would be	.....	72 cwt. 0 qr. 21 lb.		
" 2	"	"	.....	$61\frac{9}{10}$	miles per hour.
" 3	"	"	.....	$30\frac{9}{7}$	" "
" 4	"	"	.....	$27\frac{1}{4}$	" "
" 5	"	"	.....	$23\frac{3}{4}$	" "

If under *four* atmospheres :

No. 1	would be	.....	57 cwt. 3 qr. 0 lb.		
" 2	"	"	.....	$55\frac{3}{4}$	miles per hour.
" 3	"	"	.....	$27\frac{3}{8}$	" "
" 4	"	"	.....	$24\frac{1}{2}$	" "
" 5	"	"	.....	$20\frac{9}{10}$	" "

If under *three* atmospheres :

No. 1	would be	.....	43 cwt. 1 qr. 7 lb.		
" 2	"	"	.....	48	miles per hour.
" 3	"	"	.....	$23\frac{4}{7}$	" "
" 4	"	"	.....	21	" "
" 5	"	"	.....	$18\frac{1}{2}$	" "

* Should I have any future opportunity, I can, if it should appear to be desirable, reduce these, and other fractions introduced in different parts of this pamphlet, into decimals: but at present it appears to me hardly consistent to speak of any practical effect, on a large scale, in hundredths. Would it seem reasonable in any colloquial discussion undertaken with a view to decide upon and improve the speed on the London and Birmingham Railway, to say, that at that time the average speed on that line was, for instance, $21\frac{79}{100}$ (substantially $21\frac{4}{5}$), miles per hour, but that it would be brought up to $22\frac{48}{100}$ (substantially $22\frac{1}{2}$).

power and velocity.

From all that has preceded, it appears, therefore, that this mode of hydraulic propulsion claims a velocity, as due to it at a distance of 70 yards from each power station, of $27\frac{1}{8}$ miles per hour. I shall *claim* no more for it; though there are strong grounds for presuming that the formula from which I derive this velocity, is inadequate duly to measure the effect and power of liquids, when rushing up pipes of large bore; particularly if then under the impulse of a powerful momentum. In one passage, I have quoted from Tredgold's Tracts in Note D, illustrative of the principles on which his formula is founded, it is stated that the friction will be "inversely as the content of the section or as the *square* of the diameter;" but a gentleman resident in this town (Manchester) whose scientific attainments in hydrostatics are beyond dispute, and whose opportunities of testing his acquirements in the science practically, are as decidedly favourable as his opinion on such subjects is universally respected, has mentioned to me that the results of his own experiments and those of an able scientific friend, have caused him to arrive at the conclusion, that, in pipes of large bore, the friction will not be found to be reduced inversely as the square of the diameter, but more nearly as the *cube* of the diameter.* The misfortune is, that the great bulk of the experiments which form the basis

* See Note E.



down; of its being clear of, or partially obstructed by air in it; the flexures in it, so much detracted from its free efficacy; and so inadequately was the great and powerful momentum of the water, by trying the higher velocities, brought into operation; that no data so obtained, were, or could be anywise likely to exhibit the full amount of the result sought for.

Having stated thus much to set myself right with the public at large, and also to render it pretty manifest that I do not claim *too much*, I have now only to repeat that I am prepared to found my statements and deductions, confirmatory of the power of hydraulic propulsion, on Tredgold's formula: it is the best, that, under all the circumstances, I can produce; or rather, I should say, it is the one most generally accepted, and least open to be demurred at, or questioned by any parties, on the score of indicating too favourable a result. I claim, therefore, no more than 27 miles an hour—though the actual speed is more likely to prove 30 or upwards—but this is on assumption, that I take my driving velocity at that due to liquid at a distance of 70 yards from the vertical column, and control the great previous velocity down to the same rate. The velocity due to the water at fifty yards from each power station, might, probably be very safely taken as the driving speed, and each length of propulsion pipe would then, in the same degree, have to be curtailed; but it is far better to

this momentum? At the foot of the vertical column there is a weight, or load of water of 86 cwt. 2 qr. 14 lb. pressing to escape at a speed of $67\frac{1}{2}$ miles per hour. It may otherwise be termed a pent-up flood, seeking means of escape under this enormous pressure, and ready to bear before it, whatever is brought against it with a less opposing power. Now, to repeat a former statement, and save my readers the trouble of referring back, the drawing shows the machinery, attached to the communication valve. The inclined plane on the driving truck, through the agency of the pulley, &c., opens that valve at first, say, one third, so as to allow only such a supply of water through the opening, as shall at first furnish a speed of, *not quite*, 27 miles an hour. Then, as the train progresses, the aperture in the pipe under the valve, opens wider and wider, under the gravitating power of the load, so as fully to counteract the increasing retardation in the horizontal pipe, and to preserve in the water a velocity equal to that under which it first started; or rather, it will be a little increased. Now this is all perfectly easy of accomplishment. On inspecting the drawing of that part of the machinery, which is to effect this purpose, it will be found that the whole is as capable of being adjusted to the speed and circumstances under which it has to work, as a clock is by its pendulum, as a stationary steam engine, by its governor and throttle valve,

E



of the valve *a little* before a train—at the speed for which all this is to be regulated, 27 miles an hour—quits the propulsion section of piping. The air cylinder would effect this purpose by having a tap affixed in it, near the bottom, and which might be set open to what was found to be the true regulating point. This tap is not represented in the drawing; but it is all clear enough, and saves unnecessary detail there. When these adjustments are once arranged in practice—and that, in each case, they would be, in the course of a few hours—they last for ever; for all being once *set* to, and for a given speed, nothing can vary it; heavy or light trains must go before it at one even progression; as the propulsive power is, beyond all comparison, great, and most effective, but regular in its action, when brought to act upon either.

The initial propelling force, or that due at the foot of the vertical column, has been stated to be equal to a pressure of 86 cwt. 2 qr. 14 lb.; and it has been shown that its *natural rate of speed*, in that position is $67\frac{1}{2}$ miles an hour: it has also been made apparent that this speed must be controlled, so as to reduce it to that of 27 miles an hour, which, as it is the final, must also be the constant speed in each section of propulsion-pipe. The question then arises, what power (say, horse power), for the purposes of propulsion, is represented by a vertical column of water, of the weight of 86 cwt. 2 qr. 14 lb. falling—and as it falls, ap-

space. Thus, provided I employed this propulsive power on my machinery, at the velocity here due to it; then, of the vertical column of 198 feet in height, 150 feet would have to be considered as the free gravitating agent, and 38 feet as that employed in overcoming the friction due to the pipe. This is exactly in accordance with the views on this subject, expressed by the learned editor of the Tracts on Hydraulics, as may be found transcribed in Note D. But instead of taking the above natural velocity, as I may be allowed to term it, of such a column for propulsive effect, I limit the velocity to that of, say, 27 miles an hour. Hence, while in the former case, a deduction (16 cwt. 2 qr. 16 lb.) would require making, which would reduce the gravitating power to 70 cwt. in the present instance, the deduction must be as much reduced as the square of 27 is smaller than that of $86\frac{1}{2}$. This will detract from the first gravitating power, say 86 cwt. 2 qr. 14 lb. by very nearly 1 cwt. 2 qr. 14 lb.: thus leaving 85 cwt. absolutely free.

Now we can return to the former question, and easily determine the horse power, represented by the gravitating power of 85 cwt., falling freely, through space, at the speed of $27\frac{1}{2}$ miles per hour. As a horse power is represented by the free lift (or gravitating power, either) of 150 lbs. at the rate of 220 feet per minute; and, consequently, as the free lift of one ton, at the rate of

end of the propulsion pipe—must be next considered.

The rate of discharge of water, due to a pipe of one foot diameter, at its mouth, at a distance of 70 yards from the vertical column, and under a pressure of 5 atmospheres, is 40 cylindrical feet per second, (by the formula, exactly 39.8 feet per second) and this velocity, is that, due by the laws of gravity, to a free fall of 20 feet. Hence, as a cylindrical foot of water weighs 49 lbs., therefore, $49 \times 20 = 980$ lbs. = 8 cwt. 3 qrs. 0 lbs. of free, falling, and propulsive power; which at $27\frac{1}{2}$ miles an hour, is equivalent to 71 horse power. The remainder of the pressure of the vertical column, when the water has travelled 70 yards from its base, is, therefore, by the formula, to be considered as being expended in overcoming the friction due to the pipe; and on the assumption, that *so much* of the initial pressure, due to five atmospheres—which initial pressure is 72 cwt. 0 qrs. 21 lbs., will be so expended, I shall proceed with my calculations; first, only requesting my readers to compare in their own minds, the amount of this deduction, with all that has been said in the preceding pages, respecting the present state of hydrostatic knowledge, as regards the progressive force and power of water in *large* piping, at very high velocities, and under a great momentum, proportionally increased. The experiments from which the probable effects, in opinion of the experimenters, have been deduced, bear nearly the same relation or proportion to the

become literally overwhelming. Who would dare to check a locomotive, when—to use a very significant phrase—it was at its “full swing?” and yet, at that moment, and under such speed, its driving, or tractive power—from which source only, it can maintain, or feed its momentum—is usually estimated as being only that of about 800 lbs. And in like manner, who would stake his judgment on the assumption, that a column of water, which, but five seconds before, started into action, under an enormous gravitating force—say 86 cwt. 2 qrs. 14 lbs. as due to six atmospheres, under which it starts—shall, in that short interval, have so expended its power, as then to present a remaining progressive effort of hardly 9 cwt.? Water, when inclosed in pipes, is less compressible than the metals themselves; and is, under these circumstances, perhaps, best compared to a mass of molten iron. Now, of what character would the momentum and impetus be, of a horizontal column of iron, 70 yards long, and one foot in diameter; and moving as freely as water is every day observed to do, either in closed or unclosed canals, at a rate of 27 miles an hour? Iron, though less incompressible, is far more ponderous than water; that must be admitted. Let the difference then be deducted, and the estimated result calculated; or at any rate, let a just idea of the power here in question, remain impressed on the mind. It should also, never be forgotten



would be the *shock*, of the horizontal column of water, if suddenly checked, and gradually to destroy, and render perfectly harmless, the immense impetus with which it will be then advancing. When the water rushes into these vessels, it will be thrown upwards by their internal arrangement; but it will be met in them at first, by an ordinary atmospheric pressure only; that pressure however will be rapidly increased, as the space into which the air is condensed, above the water, is rapidly diminished, by the entrance of the impetuous current; until at length, the one increasing, and the other decreasing, the rush of the water will be gradually subdued, and the fluid brought again into a state of quiescence.

tortuous piping, for the supply of towns. But there is a momentum, under another character, though acquired from the first driving power, the mighty agency of which I cannot consent to relinquish, in my estimate of the effects to be produced from this mode of hydraulic propulsion. The momentum I now allude to, is every day witnessed in operation ; and is that which is absolutely inherent in a train in motion, especially when at the higher speeds. Such momentum—or, say impetus—when ungoverned, has been the cause of too many lamentable accidents, to require any further observations on the power or force while it exists, which it carries in it. Whenever, therefore, I can show that this propulsive force, or medium of force, can be rendered practically available in hydraulic propulsion, I claim its powerful agency. I shall have to bring this subject more fully under the notice of my readers, when the time comes to demonstrate its effects.

Let us now consider a train as coming under the action of one section of propulsion piping. For present purposes, it will be best to suppose that it has got up its speed ;—indeed, the mode of getting up the speed will probably suggest itself to my readers at once. It is clear, the first section of propulsion piping from any station, may be extended to a length of, say. 100 or 120 yards, and the communication valve, being set to give a very small speed at first and gradually to increase it, till it affords that due



is not worth taking into account. I may observe, the guard will be at the driver's elbow to communicate his orders, and not placed on a carriage at a distance from him ; when the noise of a locomotive train very frequently prevents his orders being heard by the driver, when the urgency of the occasion is greatest. It will be perceived that the adaptation of the truck for conveyance of merchandise, has been considered in the position of the wheels ; and that the safety of the conductor and driver have been kept in view, by placing them in the back part of the carriage, *in case* of any collision ;—the occurrence of which, though impossible in hydraulic propulsion from the usual causes—may still, at remote intervals, take place on this system, in common with every other, if high-roads are permitted to cross the lines, or cattle to stray upon them. When considering the arrangement of the conductor and driver's department, it will be evident that the truck must carry heavy goods only, to lay in the body of the carriage, such as metals, masonry, and heavy packages ; and so as not to intercept the look-out a-head, of the men in charge of the train.

* M. de Pambour, in his elaborate work, shows that the average gross loads on the Liverpool and Manchester Railway, in the year ending June 30th, 1834, were 32 tons each. This includes the weight of the goods, passengers, carriages, and trucks, but not that of the engines and tenders.—*Practical Treatise on Locomotive Engines*, second edition, p. 542.

when a locomotive first proceeds to put a train of carriages in motion. In the hydraulic system, however, a jerk of the character I am describing, would clearly not be near so rough as that which, under the circumstances alluded to, is felt in a locomotive train; for, in the latter case, the carriages have no motion in them, while, in the former, the impulse would only tend to vary their speed from 25 miles and a half, to 27 miles an hour. Any liability, however, to a sudden impulse, even of so trifling an amount, is, with the greatest facility, removed, by adjusting the communication valve to open, just at first for 25 miles, and immediately afterwards to run up the speed to 27 miles an hour.

As soon as, or the moment after, a train is acted upon by the vertical column of water, or its equivalent in pressure, I have shown that it is placed under an impulsive force equal to that of a steam engine of 693 horse power; and it will be evident, that, should the speed be increased—the first driving or gravitating load on it, being still the same—the available horse power must be advanced in a like proportion. Indeed, if it were possible to avail ourselves, for propulsive purposes, of the whole initial speed, due at the foot of the vertical column, the horse power would swell up to such a prodigious amount, that, *if the figures did not clearly demonstrate it*, I should never venture to refer to it in print.

F



which a train has to encounter, under given circumstances. Dr. Lardner states that this retardation includes the opposing influence of the air; he also points out the fact, that the retardation of the trains, which, at 30 miles an hour, he estimates at 22 lbs. to 23 lbs. per ton, decreases *very rapidly*, as the speed falls. At a speed of 26 miles an hour, he found it was $12\frac{2}{3}$ lbs., and at a speed of 19 miles an hour, 9 lbs. per ton.

Now, Count de Pambour states, as I have mentioned, that the *average* gross loads of the trains on the Liverpool and Manchester Railway, are 32 tons. This includes the luggage trains; we shall, therefore, be quite on the outside, if we estimate the passenger trains, which are the fast trains, at 25 tons gross each; we shall be also equally in their favour, and as much in excess in our estimate, if we set down their average speed at 25 miles an hour, and allow to it a retardation equal to 13 lbs. per ton. Then, as 25 miles an hour are equal to ten times the accepted speed of the ordinary steam engine, we must estimate the tractive power of a locomotive, under the given conditions, thus :

$$\frac{25 \times 13 \times 10}{150} = 21\frac{2}{3} \text{ horse power.}$$

This is all the power a locomotive exhibits in practice, under these circumstances ; it is all the power the engine accounts for. The fact is, that the machinery of locomotives, at the higher speeds particularly, runs away for its first power. This will, I think appear evident, and well accounted for, when the nume-

ture of steam and coke ; this hurried work well accounts for the great throttling of the steam in the blast-pipe ; this shows that the engine is, to a considerable per centage of power, working against itself ; in fact, it is getting forward like a horse, panting and out of wind, who has nearly enough to do to carry himself, and has not time, while he hurries along, to recover his breath. When all these circumstances are borne in mind, I think it will not be considered, I have been guilty of the least exaggeration, when I have asserted, that the driving machinery of locomotives must, from the very arrangement of the engines, particularly at the higher speeds, recoil and run away from the first impelling power, before it has time to act profitably on that machinery.

But whether the tractive effort of a locomotive engine, at a speed of 25 miles an hour, and drawing 25 tons, be 800 lbs., as it is usually assumed, or 325 lbs. as the preceding data, borrowed from the work of M. de Pambour, and the lectures of Dr. Lardner, would appear to render much more probable, its whole available force will be found to be small indeed, when compared with that which is inherent in hydraulic propulsion. A locomotive exhibits, at its utmost capability, as respects an average speed, a tractive power of, say 325 lbs., while hydraulic propulsion, at the foot of the vertical column, shows, from figures, at the adjusted fixed

cient; the grounds for which will be made to appear, as we pursue our inquiry into the mode of operation, and of the effect of the gravitating power of the vertical column, as soon as it is brought to act upon the piston; and which—having now by comparison, explained the exact position of the system at this point—we are about to resume.

As the figures, derived from sound—or, at any rate not too favourable data—show that the propelling force at the foot of the vertical column, acting through the travelling piston on the train, is equal to 693 horse power, it is clear to demonstration, that such an impulse must carry before it any string of carriages or trucks, that were ever linked together on a railway; and this, with perfect facility, and, in a manner, without effort. If they are at rest, it will start them without difficulty, and quickly run up the speed; if, on the contrary, the carriages are then at nearly the usual travelling velocity, it will restore all that is deficient in it, as soon as ever the sufficient opening of the communication valve permits this to be done without jerk, or roughness. But perhaps some of my readers may here wish to object, that this enormous propulsive agent decreases in power in a very rapid ratio. Most certainly it does, as I have already demonstrated. Hydraulic propulsion is of this nature: it will first fling into the train an *irresistible* momentum, limited in respect

up the propulsion-pipe by the closing of the stop valve, will shoot itself up the connecting piping, into one of the air vessels (S) which I have already alluded to. On throwing up the mouth valve, and entering such receptacle, it will be met by an inclined plane or curve in it, so arranged as to drive the propulsive current up, that it may—until the air pressure in the vessel becomes more condensed—exhaust its first force against the dome, instead of impinging violently against that side of the vessel, which would otherwise be opposed to it. But to return to the subject of the momentum; I shall require the aid of this force to drive the train only 150 yards, that is over the next alternating section of skeleton piping.

A heavy train, on the present locomotive system, cannot be stopped conveniently in less than a quarter of a mile; and then we hear the breaks creaking, to present all the obstruction of locked wheels, to the momentum, which otherwise would carry the train forward a considerable distance further. Now, if a train, with the small maintaining power at present upon it, exhibits so great an amount of progressive force, what impulsive effort will it be capable of exerting, when it borrows its momentum from a power so prodigious as that which I have attempted to describe; and which comprises the whole propulsive effort of an





to the trains in motion, undertook several experiments on the Sutton incline. In the course of one of these, mentioned in his second lecture, two coaches, weighted to the gross load of 11.33 tons, were brought to the top of that incline, and then suffered to descend by gravity. Now the Sutton incline is one in 89, and, according to M. De Pambour, 2,446 yards in length; and, at the foot of it, there is what may, for all practical purposes, be termed, a level, as it presents an incline only of one in 2,762, and which has a length of 4,241 yards. These coaches, in descending the incline by their own gravity, acquired a speed, the lecturer observed, of 28 miles and a fraction; and they ran, in all, a distance of 4,577 yards. Deducting from this, the length of the incline, it appears they were carried over 2,131 yards of level, by their momentum alone; their speed, at the commencement of this level, being, say 28 miles an hour; and their loss in velocity accordingly, being, at the end of the first 150 yards of level, at the rate of $1\frac{7}{8}$ miles an hour, as near as possible. This loss, then, I will allow for the passage of a train over a skeleton length of piping; and, deducting it from the final speed, $27\frac{1}{8}$, due to the end of a section of propulsion piping, I have for my final speed at the end of a section of skeleton, that of $25\frac{1}{4}$ miles an hour; and at this speed, it may be considered as entering the next propulsion-pipe.



found to be $26\frac{1}{2}$ miles an hour. If this very slight decline in speed, in producing an average, is worth consideration, it might easily—and where new railways were forming—economically, be avoided, by making each line a waiving one. It would be effected thus: let the gradients usually be such, as that the trains shall ascend, along that part of a railway over which a section of propulsion-pipe extends, at the rate of, say one in 100, and descend at the rate of one in 200 over that, carrying a section of skeleton pipe; the gravity and momentum together, thus compensating, for the very trifling retardation, otherwise here experienced in the speed of a train. An ascent of one in 100, or even one in 50, I think it might easily be shown in figures—if I might further be allowed to detain my readers—would not sensibly affect the speed of a train over the propulsive piping, as the driving power there is so enormous. In fact, the gradients, which this system of propulsion would easily overcome, are of a character so dissimilar, in point of steepness from those we thus far ever have met with on railways, that I would rather leave it to others to describe them, than hazard the charge of exaggeration against this little pamphlet, by undertaking this on the present occasion. A calculation of this sort would be most simple. Deduct so much from the propelling power, as will be absorbed in meeting the retardation due to a given train at a given speed, and the

by enabling the directors of railways to keep a system of very moderate fares ; and this again would re-act in favour of the shareholders, by, in all probability, much increasing the traffic.

In fact, the difficulty of rendering steep descents practicable and safe, would be greater on this system—as it would be on every other—than that of overcoming the ascents. No propulsive apparatus, of course, would be required for that line of the rails, which carried the descending train ; and where the descent was not very considerable, the difficulty might be practically overcome, by the beautiful contrivance which is adopted in the celebrated Box tunnel, on the Great Western, near Bath ; and in which, before such means were taken, the descent was found to be inconveniently steep. Where the descents were very rapid, it is possible the iron rails might be entirely dispensed with, and strong wooden longitudinal sleepers laid, in place of them, with deepish grooves cut in them, *to fit at the bottom, the vertical transverse section of the periphery of railway wheels*, and with steep slanting sides to such grooves. If this could be worked out in practice, it would oppose a very considerable friction to the progress of a train, which might otherwise gravitate too fast. When the wood had worn a little, such longitudinal wooden rails would be improved, as regards the object here in view, not deteriorated.

parody the celebrated sentence of the great mechanician of antiquity, an hydrostatic philosopher of the present times, might truly exclaim, "Give me but time, and I will send the power of water, under a vertical head, in piping, from one end of a county to another."

But as one of the first desiderata in any railway system, is to overcome time as well as space, the laws of hydrostatics require that, to preserve velocity, the propulsion-pipes should be comparatively short; and it has only been by combining, under the requisite conditions, the apparently dissimilar action of two leading principles in hydrostatics—slowness and extended operation, and velocity and contracted operation—that I have felt myself enabled to offer to the public, a practical and powerful system of hydraulic propulsion.

From all that has preceded, it appears reasonable, that a propulsive-pipe should not be shorter than 50 yards, nor longer, for the higher speeds, than 100. Well, then, thus far I show a train practically driven over some 70 yards of propulsion-pipe, and about some two or three hundred more of skeleton pipe, and that is all. The great inquiry now comes:—Can this mode of action, by any manifest and simple means, be continued? This inquiry I answer by the following statement. The retardation of water in piping is very trifling indeed, when it travels at a slow speed; in fact, at last, it becomes a mere shadow, and may be called

medium of an extra pipe, of smaller bore, provided for this purpose. Let there be also a short pipe, connecting this receiver with one end of a section of propulsion-piping—just as would be the case at a first power station; let this pipe be of the same bore as the propulsion-piping—or it might advantageously be a little larger, if, at its junction with the propulsion-pipe, it presented a conical-shaped termination. Now, the propulsion receiver being duly “charged” with water, under a pressure of six atmospheres, open a valve in this connecting pipe, and what happens? The water in the receiver, instantly shoots up the propulsion-pipe, *under a pressure of six atmospheres*. Does it so continue to the end of the pipe? No. The space above the water in the receiver occupied by the compressed air, which, before the valve was opened, was equal to five volumes of the water now discharging, will, by that discharge, ultimately become equal to six such volumes; and the pressure, which, in the first instance, was 6×5 will then become 5×6 . This alteration in the pressure will clearly be gradual, and the change will be complete, just as the communication valve in the connecting pipe, closes again, on the propulsion-pipe having received its due charge of water. This will render clear to every one, the propriety in working the propulsion-piping, of starting the water, as in the preceding pages I

quently when this occurs, it may be turned to very beneficial account. The vertical heads of water now alluded to, can only be expected to be found in the vicinity of high grounds; and such localities are the places, where it would frequently prove equally convenient and economical, if very considerable inclines could be well overcome. This final pressure of $6\frac{1}{2}$ atmospheres, would, in all such cases, allow of the propulsion-piping being lengthened, so as to extend the driving effort, and still afford a final velocity of $27\frac{1}{2}$ miles an hour, while at the same time, it might overcome a very considerable incline; or should the incline be short and steep, like a hill, the propulsion-pipe might remain of the ordinary length, and, *preserving the speed*, the trains, by this extra power, might be lifted on to this higher level with no more *apparent* effort than a sloop is lifted, in a lock, from a lower to a higher level in a canal.

But to return to the propulsion-receiver. The capacity requisite to fulfil the preceding conditions, will be found to be amply provided for, if the receivers are made of a conical shape, of nine feet six inches diameter, and of twelve feet height in the cone or barrel, surmounted at the top by a half-spherical dome, and consequently measuring vertically through its centre, four feet nine inches, and finished at the bottom by a dome, measuring, in the same direction, two feet four and a half inches. They might advantageously be formed of thin wrought iron, if of $\frac{1}{4}$ to $\frac{5}{16}$ in

station occupied during one of the intervals in the passing of trains, in "charging" a single propulsion-receiver. This, however, would be the work only of two or three minutes, as I shall have occasion to show further on; and, besides, one propulsion-receiver would only constitute a medium for conveying and applying the propulsion force of a first power station, to a second section of propulsion-pipe, and thus, with the aid of the momentum of the train, over the contiguous length of skeleton. There must evidently be a series of the propulsion-receivers provided, which must extend along the railway on both sides—to the right and left—of the first power station, for a considerable distance, though only on one side of the line. In fact, the distance must be limited only by the number of propulsion-receivers, which the available force at the first power station shall, under given conditions, be found capable of charging during the intervals—arranged, of course with a view to regularity in time—between the passage of the trains.

It will be apparent that by an arrangement of this character, I am preparing to unite, for beneficial co-operation, the action of the two important laws in hydrostatics—which I mentioned some few pages back, as being dissimilar in their mode of operation—for the perfecting and completion of this mode of propulsion.

of a steam engine. This steam engine we will suppose to be, on the Cornish pumping principle, and of 50 horse power. Now let us see what it will do; over what lengths of railway it will drive; and what intervals between the passing of the trains, for this work, it will require.

Such an engine of course, will be single acting, and work with a plunger or ram; that is, as a force-pump, not as a lifter. It must, as usual, be provided with a powerful air vessel, to keep the current of water running and charging the propulsion-receivers, during every alternate, or return stroke, when it is clear the engine itself, will not be acting on the liquid.

A 50 horse engine is a machine, which, after overcoming the friction of its own machinery = 7 lbs. per horse—shall be fully and easily capable of exerting a free power, equal to 150 lbs. (a horse power) multiplied by 50 ($150 \times 50 = 7500$ lbs. = 66 cwt. 3 qrs. 24 lbs.) and of doing this, that is, of exerting this lifting, driving, or forcing power, at the rate, or—if taken longitudinally—over a space of 220 feet per minute. Now this machine must apply its power upon the propulsion-receivers, to charge them, through the medium of a pipe, which must run up one side of the line, under those vessels; and which, in the reference to the drawing, I have named the “receivers’ feed-pipe.”—I now beg to refer to the drawing and reference, as exhibiting this pipe, and propulsion-receiver, and also the valves belonging to this

power station to work it.

It appears, that a diameter of seven inches (inside) will be a very convenient one for the receivers' feed-pipes, as it will provide sufficient capacity, without large dimensions or weight, and will present an area of as near as possible, one third that of the propulsion-pipes. Now, I have already stated, the line of propulsion-receivers on each side, or to the right and left hand of a first power station, is to be charged from the power there established; consequently, in the present case, the steam engine will be employed in charging two receivers, one on each side of it, at once. The engine, therefore, and its forcing machinery, must be of a capacity to work the water up two feed-pipes at the same time, *presenting together, an area of two thirds of that of the propulsion-pipes*; and I may add *only* two thirds; for, by this arrangement, we accomplish the feeding of the receivers by a power, only two thirds of that, which would have been required, if the area of the two feed-pipes, branching right and left from the first power station, had been together, equal to the area of a propulsion-pipe.

Before I proceed in my inquiry, into the working effect of a fifty horse engine, on a hydraulic railway, let me here remind my readers, that I have previously mentioned, I should occasionally require the aid of an extra half-atmosphere of pressure, at my first power station; and it is now that such will be requisite.

opposing power, varying from five to six atmospheres—the length of time it will take in doing this, in the several circumstances, in which it will be required to accomplish it, will be minutely stated, a little further on.

Now, to preserve all the clearness and simplicity possible in these calculations, let us revert to the power, load, or pressure, which in a former part of this pamphlet, was found to be due under 6 atmospheres, to the area of the propulsion-pipe ; then we will add to that power, the pressure and load due to the extra half atmosphere, (equal to $16\frac{1}{2}$ feet of water, vertical) and of the amount so obtained, we will take two thirds, and set the same down as the free impulsive power, which, it has just been explained, the engine must exert. We shall then consider what proportion this power bears, with that we have already assigned to the engine, and so we shall pass on to determine the time it will take on each occasion to accomplish the work, which it will be required to perform.

The pressure, or available force of six atmospheres, upon an area of one foot, (that of the propulsion-pipe,) is 86 cwt. 2 qrs. 14 lbs. ; to which, add the pressure of an extra half atmosphere, (7 cwt. 0 qrs. 24 lbs.), and we have, as the whole gravitating power of $6\frac{1}{2}$ atmospheres, 93 cwt. 3 qrs. 10 lbs. Now, take $\frac{2}{3}$ of this, and we shall find, 62 cwt. 2 qrs. 7 lbs. will be the free power

which I shall show the steam engine will be required to exert. This, in fact, represents the gravitating power of $6\frac{1}{2}$ atmospheres of water, when pressing on an area, $\frac{2}{3}$ that of the propulsion-pipe, and the engine will have to perform the work of such gravitating power; but it has already been shown that an engine of 50 horse power, exerts, with ease, at its ordinary work, a moving force equal to 66 cwt. 3 qrs. 24 lbs. There will, therefore, remain in the engine, unapplied, an amount of force equal to 403 lbs.—nearly three horse power; but as it is desirable that the machine should have a light, rather than a full load, I shall not propose to reduce the horse-power of the engine.

It now remains for us to consider, in connection with the present subject, the number of propulsion-receivers, such an engine can charge within a given interval; and this will give us the length of railway, over which such a machine will have to afford propulsive power to the water.

It appears a reasonable thing to assume, that a working railway day on any extensive line, will consist of 16 hours; and if the trains were large—as they might be advantageously on this system—the day traffic might probably, with very few exceptions, be performed conveniently with 24 trains. Now, this number of trains, divided over a space of 16 hours, would allow an interval of 40 minutes between the passing of each. Within such an interval then, the 50 horse engine must complete each series of its work. That series, I find, will comprise the charging of 19 propulsion-receivers; that is, nine on each side of the engine, and one immediately before it. This last will be requisite, as the engine itself will not force the water forward with anything like that velocity at which it must be worked. The engine will accumulate power comparatively slowly, and the propulsion-receivers, throw it forward at a great velocity; and this, for reasons already given, when referring to the action of two great laws in hydrostatics. The object in view, in the last named receiver, which would here stand immediately in front of the engine, may however, be obtained conveniently enough in the air vessel, through the agency of which, I have mentioned the engine to preserve a constant stream of water flowing up the receiving pipes; this I now propose, shall act also as a propulsive receiver. This receiver and air-vessel conjoined, therefore, has

vessel, it will be conveyed into the other propulsion-receivers.

The 50 horse engine, we are at present considering, will only be enabled to throw the water forward, up the two branches of such a feed-pipe, as that we suppose in connection with it, at the rate of 220 feet per minute—that being the average steam engine speed. But a propulsion-pipe contains 210 cylindrical feet of water, and as the area of the feed-pipe is only $\frac{1}{3}$ of that of a propulsion-pipe, this content of 210 feet of water will, in the latter case, be extended over three times that length, or 630 feet; and this is the length of the column of water of the reduced area, which the engine must throw into each of the receivers—charging a pair of them together, on account of the diminished area of the horizontal column—to constitute a full charge for each section of propulsion-pipe. Now, the lifting or forcing forward of any thing, which is a load for an engine, over a distance of 630 feet, is very nearly three minutes average work for such engine, and the *two* columns of water, which the engine has to throw up the feed-pipes, right and left of it, constitute such a load. Hence, if the retardation of the water in the feed-pipes was so far overcome, by the preponderation of the column of water, or an equivalent load, in favour of the engine, as to allow of the liquid being passed up these pipes at a much higher velocity, the engine could not, under the explained conditions, accomplish it. It would, however, be very different when these

are charged from a vertical column of water; for that
 of almost any speed which the retardation
 and wherever such a column can be found,
 receivers, which are least removed from the first
 are charged accordingly, much more quickly
 An engine, certainly, might be adjusted to
 any arrangement; but the better method
 is to increase the speed of the water, but the size of
 the pipe, that is, if this were ever required; in either
 case, a proportionably increased engine power would
 be required.

Now, as I have stated that the engine must take as its load a
 double column of water, of seven inches in diameter, and force
 it up the two branches of the feed-pipe, it follows, as a steam
 engine can lift or push its load 660 feet in three minutes,
 that, appointing the engine in question to charge a pair of pro-
 pulsion-receivers—being equidistant from it, on the right and
 left hand—with 630 longitudinal feet of such double column of
 water, would constitute a short three minutes work for the en-
 gine; provided its free action, at that speed, were not affected
 by any retardation in the pipes. Thus—bearing this process in
 mind—the engine, having to charge one propulsion-receiver
 standing directly in front of it, and nine pairs on each side of it,
 will be able to accomplish this series of work within thirty
 minutes. But this apparent result must be qualified in the fol-
 lowing manner: first, the single receiver, taking, through a pipe
 of proper bore, the whole water, from the engine till its own
 charge is complete, will be charged in half the time that a pair
 would require, that is, in $1\frac{1}{2}$ minutes—or something less, if we
 took the power of the machine at its full average working rate—
 next the six pairs, nearest the engine will be charged in the time
 just stated as due to the work ($6 + 3 = 18$) for the retardation
 due water travelling up to a pipe of seven inches bore, at the
 very low velocity of 220 feet per minute, is too small to retard
 the work within that length of pipe, which will reach to the sixth
 pair of receivers—each of which will be placed at a distance of
 1,320 yards from the engine;—then, the seventh pair—220
 yards further removed—will be charged in three minutes and 17
 seconds; the eighth pair—220 yards further removed—will be
 charged in three minutes and 30 seconds; and lastly, by the
 ninth pair—220 yards further removed—will be charged in
 three minutes and 50 seconds.

Thus, though I have made the preceding calculations, for the propulsion power being required about once in forty minutes, it appears highly probable that a 50 horse engine might drive a train over an extended length of railway, once every half hour, if there were occasion. The nature of the propulsive agent ensures great regularity as regards time, and the momentum of the very powerful columns of water, both in the propulsion and feed-pipes, appear very likely to cause all the work to be accomplished at a more rapid rate than I have, in this pamphlet, set forward in my calculations, as being due to it. Should any enormous amount of power, in considering future prospects, be thought desirable for any of the greater lines, feed-pipes of $9\frac{1}{4}$ inches diameter might be charged, for the length of line I have considered as under the action of each first power station, in 17 *minutes*; or the length of line acted upon by each power station, might be extended to three miles, when such feed-pipes would take 22 *minutes* to charge them; but pipes of this diameter would require a power equal to, from 70 to 75 horse, to work them with full effect. Before I dismiss this subject of speed, in its various proportions, I may here be allowed to allude to the present speed in the locomotive system, and to compare it with the anticipations on this subject before locomotive engines had been brought into great practical operation. Mr. N. Wood, in his celebrated "Practical Treatise on Railways," states that, in his

and suction piping, and a few valves, &c. for the second line of rails, it will not occasion much more expense to establish this system of hydraulic propulsion on a double railway—one of the ordinary arrangement—than on a single one; which with a large traffic would be most inconvenient, if not absolutely impracticable. The same driving force at the first power stations, and the same propulsion-receivers and feed-pipes, with their valves, would do a very large amount of work on a double line, as well, and in fact with more facility, than on a single one; and, as respects propulsive effort, $2\frac{3}{8}$ miles of double line, are equal to $4\frac{3}{4}$ of single line.

I believe I have not yet mentioned the night-work, which usually implies the passage of the luggage trains. Under the present system, these travel, from motives of economy, at a much slower speed than the passenger trains. Mr. Wood, in his work, estimates that a locomotive engine which, at 20 miles an hour, can drag $98\frac{1}{4}$ tons, at 30 miles an hour, will only draw 27 tons! With hydraulic propulsion, there would be no occasion for this great loss both of speed and time. From my estimate of the duration of a railway day, it will appear there are eight hours left for night; and within this interval, 12 luggage trains at least might be conveniently passed over a railway. I am not aware of any line that has to afford conveyance for this number of heavy

luggage trains nightly; there are, however, occasionally night mail trains; and these might take their share of propulsion among the rest.

It will be perceived, that in the latter pages of this little work, I have viewed the drawing power for the system, nearly as if the steam engine was the only source from which I could derive a first motion. This I have done for two reasons: first, it has been objected against hydraulic propulsion, that vertical heads of water of requisite altitude, will seldom be available. As regards many lines—or a considerable portion of them—I admit this objection in its full force; and as regards others, I admit it with two qualifications; the first is, that wherever railways now formed, pass under the spurs of hills, or through them by tunnels, there will be occasional opportunities, more or less frequent, according to circumstances, of taking advantage of good powerful heads of water, of at least $6\frac{1}{2}$ atmospheres, hydraulic altitude, —214 feet—and when they *can* be found, economy dictates their useful application; and that they will occur more frequently than might at first be imagined, appears probable enough, when we bear in mind, that those lower elevations, near which, railways occasionally pass, are frequently the abutments of higher hills; and without going a quarter of the distance, that water-works Companies sometimes fetch their water, when offered them under such inducements; and by the aid of supply receptacles, extremely small when compared with their dams, I cannot but think the quantity of power economically to be derived from such sources, will be very far from contemptible. My second qualification to the objection, is stronger still. It applies to lines that may be formed with a view to availing themselves of hydraulic power. These will naturally seek the vallies among the hills and mountains, and court the contiguity of high grounds, which elevations must often furnish abundant hydraulic power, to overcome with ease the undulation of the country, and to drive a large traffic at a very trifling cost indeed. I hardly need say, that there can be no binding necessity for the first power stations being distant from each other exactly $2\frac{3}{4}$ miles. Good falls of water would at any time, to a certain extent, influence their locality, and whenever one presented itself, ny where between two and three miles from the last station,

would be fixed upon as the spot for the next. But whatever advantages may ultimately accrue to the system from such sources, the whole tenor of this pamphlet, I trust has made it apparent, that I do not consider hydraulic propulsion should look for that success which I think it deserves, mainly for the frequent aid of natural vertical heads of water; and this, particularly in the case of railways already formed. I think I have already shown, it has very great power independent of such aid; and it will remain for me, in the same circumstances, to prove its great economy.

I must now explain the second reason, for which I have latterly viewed the steam engine, as nearly the only first agent for charging the propulsion-receivers. It is this; the steam engine has become throughout the country so perfectly the popular representative of power, that when a working force has to be estimated, it is most conveniently done through the medium of this deservedly popular machine. But then it should, at the same time, never be forgotten that there are many other machines. Water wheels, Barker's mills, and those powerful water machines of the steam engine construction, as respects cylinder and valves, which bear the name of hydraulic engines, might all occasionally be brought in to aid the working out of this system, with powerful effect, and with a view to its most economical arrangement. A low fall of water, if of sufficient volume, will drive almost any hydraulic machine, so as to do the work of a steam engine, without the cost in fuel. To such an extent might this principle be sometimes carried on railways, as to cause one stream of water to do, in a manner double work. Thus, a stream conducted down from the head of a deep cutting, might first work a water-wheel, for instance, on the level of the railway; and, afterwards, the same stream of water might be conducted some distance, in a proper channel, along one side of the line, till brought to the top of a high embankment, down which it might be thrown upon a wheel beneath with considerable effect. The power from the water wheel, would, with much ease, be brought up again to level of the railway, to be there applied upon a contiguous power station: hence, many advantages may be expected to accrue to this system, which will not show themselves of the calculations.

CHAPTER VII.

The apparatus for bringing hydraulic propulsion into a state of practical application on railways, is exhibited in the drawing; and a short description of it will be found in the reference to the figures. But to that description, it now seems desirable to add a few particulars, which could not conveniently be given there.

The continuous cleft in the propulsion-pipe, it will be observed, presents in section the outline of a truncated cone, being narrower at the top than the bottom. Hence, the continuous flexible valve will have a disposition to fall out of this cleft to the bottom of the pipe, when the water in the propulsion-pipe pressing it upwards, and holding it in the cleft, is drawn off: at the same time, the pressure, being so very great, may occasionally fix it there too firmly to allow of it falling out by its own weight, when the liquid has done its work, and has again been withdrawn. In either case, the machinery is arranged for the satisfactory action of the valve; if, as in the first instance, the continuous valve is found lying along the bottom of the pipe, as the travelling piston advances before the column of water, its guide-neck, with the long snout it presents in front, takes it up, and allowing it to slip between two guiding ridges, up the inclined plane which its back presents, passes it, in a manner *through* the connecting plate, before this plate is itself carried through the continuous cleft, in order to attach the train to it for the purpose of propulsion. This is effected by causing the plate to divide, arch-fashion, just before its junction with the guide-neck, thus affording through it, a free passage for the continuous valve. This valve is then slid over the forehead, or highest part of the incline, and so placed loosely in the cleft, before the piston itself passes; as this takes place, the water by which it is driven forward, on reaching the valve, pressing on its under surface, ~~wades~~ it (I may almost express it) firmly into the cleft; and

air-pressure, varying from $97\frac{1}{2}$ lbs. to 75 lbs. on the

square inch there can be no doubt whatever that the pipe will be then perfectly water-tight; that, in fact, for the time being, it will be most effectually corked. Now, on account of this wedging of the valve, it is possible it may occasionally not fall down into the bottom of the pipe, as I have anticipated, even though the formation of the cleft is such, as to make it appear difficult for it to retain the valve, when a pressure underneath no longer exists. But, supposing this to take place, the machinery is also arranged to meet the contingency. The arrangement is most simple; it consists of two small pulley wheels, attached to the driving truck, and placed one before the other, a little in front of the power-connecting-plate, in such a manner as first to loosen the valve in the cleft, and then to put it down; when it will be in a most convenient position for sliding along the upper part of the guide-neck, and so taking its place in the cleft again above the piston.

The materials of which this continuous valve should be composed, and the manner of its formation, must be explained: and first of its formation: let it be done thus; form a mould, say of clay or plaster of Paris, whose transverse area shall be the same as that of the valve, to be constructed; and within this mould, before it is completed, stretch well apart, a series of small strands of wire rope, or strong single wires, longitudinally; then, transversely, fully half fill it in a systematic manner, with short and moderately thin bits of very hard wood or whalebone, of the same length as its transverse section, in the different parts of it, where the wood is placed. When all this is well arranged, the material for filling up the interstices, only remains to be pointed out and applied; this is caoutchouc or India rubber; which in a liquid state, must be poured in, to fill the mould. It will now, therefore, be evident that the intention is to *cast* the continuous flexible valve in a mould. When dry, the valve is made and ready for use. The wire strands will prevent the continuous valve from stretching longitudinally; and the bits of wood or whalebone, will prevent it from contracting transversely, in any inconvenient degree, when subjected to the high pressure, which it will be required to sustain.

It will be observed, that a stout wire is made to stretch section of skeleton-pipe, just the same as the continuous

does, through one of the propulsion-pipes; in fact, the valve and rope, being always linked together, keep up one unbroken line. This is merely to preserve the connection between one section of continuous valve and another. The wire rope will consequently pass over the guide-neck and piston, as the train goes by, in the same manner, but more loosely, than the continuous valve itself does. The whole of this apparatus will require, before being put in use, to be subjected to a great tension, to prevent after-stretching. It will then work with great truth, as there will be seldom where more than about seventy yards of the continuous valve, or 150 of the wire-rope, exposed at once to any draft or pulling from the travelling piston—small, though it will be—for each length of the continuous valve, when fixed in the cleft, by the water pressure under it, will be quite immovable, and will constitute a strong holding power, which will not be wholly relaxed, till some time after the travelling piston has passed over the adjoining section of skeleton, and entered the next of propulsion-piping. The power-connection-plate should be two feet in breadth, and $\frac{3}{4}$ or one inch in thickness, which will leave nearly an inch play in the cleft, on each side of it. These proportions will combine great strength, without any inconvenient degree of thickness.

There is a peculiarity in the formation of the piston, which nearly obviates the whole of the friction, that might very naturally be supposed to be due to such an apparatus, when travelling within a confined space, at a speed of nearly thirty miles an hour. The piston must, of course, be formed of the best wrought-iron. This will allow of its being made with a view (comparatively) to lightness, particularly in the feather extending below, on each side of its guide-neck, without sacrificing that requisite degree of strength, which should distinguish the apparatus.

Now, no part of this iron piston ever touches the propulsion or skeleton pipes, up which it moves; some rings of leather, or India rubber, which are fastened down to it on one side and quite loose on the other, only coming in contact with the sides of the propulsion-pipe. The piston is supported vertically behind, by one pulley or friction wheel, and before, by a pair—between which the continuous valve passes; thus, in the vertical line, it is evident the piston cannot touch the piping, as, in fact,

it runs upon wheels within it. In this direction, however, it approaches nearest to the pipe at its forward, just above the arch-way, through the power-connection plate; and, even here, it should be fully half an inch below the pipe. In the horizontal direction, it is protected from ever running or drawing against the sides of the pipe, by another friction wheel, placed forward, to guide it as truly in that direction, as the others will in the vertical. This horizontal guiding wheel, it may be remarked, is placed, as well as the vertical pair, in the guide-neck; but this, in speaking in general terms, must be understood as included in the common designation of piston. Now, the piston itself, that is the latter barrel, or cone-barrel portion of the apparatus, will, as may be perceived by the drawing, approach in no direction, within $1\frac{1}{2}$ or $1\frac{1}{4}$ inches of the sides of the pipe. This statement at once renders it unnecessary on me to explain here its requisite water-tight quality will be obtained. A series of rings of leather, or of caoutchouc, of a breadth of about four inches, are to be well rivetted down to it on one side, that nearest the guide-neck—and on the other, are left perfectly free; thus, if a very powerful blast were blown up the pipe, behind the piston, three or four of the last of these rings would expand, or open on their loose sides, with which they would then press against the sides of the pipe, and, sooner, surely, would intercept the current. The very same thing will occur when the propulsion water presses on them from behind, with this difference only, that, as the liquid will wet them, they will more effectually, and with more facility, prevent its pressing on further, than say, the fourth or fifth ring; or, if it ever should be getting a little more forward, the slight chatter, or quick, but almost imperceptible shaking of the apparatus, as it rushes on at a great velocity, will, very quickly, throw it back. The most easy way of imagining the working of these rings, and the manner they will be thrown open by the liquid is, by recalling to mind, the opening motion in the water, of the gills of a fish. I think this series of rings, say, of caoutchouc, may very properly be termed the piston-gills.

The nature of the preceding remarks will make it very clear, there can be no occasion to bore the propulsion-pipes. Let them be well cast, with plaster of Paris, or other good cores, and the boring of them would, I imagine, become a most

does, through one of the valves, in this respect, will be and rope, being always in the same line of the finished line. This is merely to prevent the valves otherwise require to section of continuous valve consequently pass over the valve goes by, in the same continuous valve itself does, quire, before being put in position, to prevent any possibility, truth, as there will be yards of the continuous at once to any draft of piston, though it will be—fixed in the cylinder, quite immovable, and which will not be when the travelling piston has passed and entered the next or section-plate should be of thickness, which will leave each side of it. These pistons without any inconvenience.

There is a peculiarity in nearly obviates the whole of the cylinder, really be supposed to be due to the piston lying within a confined space, in an hour. The piston must, of wrought-iron. This will allow (comparatively) to lightness, placed below, on each side of its guide, a requisite degree of strength, which.

Now, no part of this iron piston or skeleton pipes, up which it moves, India rubber, which are fastened quite loose on the other, only connect the piston with the propulsion-pipe. The piston is held back, by one pulley or friction wheel, between which the continuous valve, line, it is evident the piston cannot

be moved in this pamphlet, which is nearest to the water. The valve, against accidents, and the valve, can immediately be closed up to the truck; working the above valve, It is, however, that stray cattle, or a line of rails, on which immediately after a communication, to furnish its supply, and to retain this valve; the propulsion water being driving it before it. It is to work this trifling valve, appearance of complication, of this system. This necessarily placed behind the valves, which are to open or closed out through the cleft of the train. This, myself, be found to be. If the line of rods, high, they will, I think, mode of action; and if, away, and the other, machinery be then to decide, whether mechanism, namely,

have, on a few accidents on

railways. There are several instances of large blocks of wood, or huge masses of stone, having been laid on the rails with the avowed intention of overturning the trains ; again, serious obstructions may be left on a railway accidentally.

Now, whether obstructions on a railway, occur from pure accident, or a most culpable negligence, or from a depravity of mind, much lower than the tone of feeling which belongs to the most degraded of the brute creation ; and however unfrequent any of these things may be, still any party who proposes to make material alterations in the arrangements of railways, should be ready to show how he is prepared to obviate all obstructions, from whatever cause they may arise, at least, in so far, as his own machinery is concerned. Let it be supposed then, that any depraved and most wretched person threw a lump of iron, or any strongly obstructing substance in a propulsion-pipe ; what would then occur ; judging only of the machinery from what had been already explained ? There would be a partial shock just as the momentum of the train snapped the iron straps, which attached the power-connection plate and piston to the large pair of strong springs under the truck ; but after that, the train would proceed, as if nothing had happened, till its momentum was exhausted, and it came to a stand. The piston itself, however, would be seriously damaged, and a proportionate expense would be incurred in its repair. Now this expense might be easily much reduced, and the shock, which, otherwise would be felt through part of the train, might be so much lessened, as probably not to be materially perceptible, even in the travelling truck. It must be borne in mind, that the business of the piston is to push the train forward, not to pull. To give it any required capacity of pushing then, place a shoulder on the springs, against which the front end of that part of the top of the propulsion plate, which is strapped or bolted to them, shall abut firmly. This simple contrivance will afford any ability for pushing a train forward, that may be required. Then let the iron straps, which, with the bolts, attach the connecting plate to the springs, be, comparatively speaking, slight ; when, if any serious obstruction were encountered by the travelling piston, the straps should break ; without any great shock, or materially damaging it, the

fluous expense. The amount of one of considerable moment pipe is compared with the cost to be expended on it.

The piston, as I have intimated, has a protecting valve at the top. It is placed there as an extra might be dispensed with, as it is—which opens the communication thrown out of gear, or rather when, as it would, miss the no supply of propulsion within reach of possibility. A deaf person, might be observed the train was running, as the action valve had been there for 70 yards; and, therefore, small extra expense is incurred which has, for its object, a shot through the piston rather remarkable, that it carries with it, probably, more than any other part of the engine arises from the valve its power-propulsion plate. To close it, must also, of necessity, in the propulsive-pipe be placed back for the convenience of the complication, however, which only so in appearance, and not belonging to this valve, are to be found to be simple enough for a moment, *they are* important and far more important, part of the engine. When examined, it will remain for it to possess those first characteristics of simplicity and aptitude, for the

Attempts, which may be told on occasions, been made to remove

the piston, as I have intimated, has a protecting valve at the top. It is placed there as an extra might be dispensed with, as it is—which opens the communication thrown out of gear, or rather when, as it would, miss the no supply of propulsion within reach of possibility. A deaf person, might be observed the train was running, as the action valve had been there for 70 yards; and, therefore, small extra expense is incurred which has, for its object, a shot through the piston rather remarkable, that it carries with it, probably, more than any other part of the engine arises from the valve its power-propulsion plate. To close it, must also, of necessity, in the propulsive-pipe be placed back for the convenience of the complication, however, which only so in appearance, and not belonging to this valve, are to be found to be simple enough for a moment, *they are* important and far more important, part of the engine. When examined, it will remain for it to possess those first characteristics of simplicity and aptitude, for the

It has been said that the piston, in the ordinary works from the piston, without being placed in the station, or when down, the piston passes as the piston. This current of current and the piston are cut off from the piston-pipe, the piston, where the piston end of the piston, where the piston

the quick, or tardy opening of the communication, and the stop-valves will be reversed. The seat of the communication valve, if inclined at all, will then be in the other direction, and its projecting leaf, which is to assist in throwing the valve up, will be made lighter, so that the mere pressure of the horizontal column of water of one foot in height—when the great vertical supply or pressure has been cut off—shall hold the valve to its seat for a short interval, while the stop valve, with (in that case) a greater gravitating power in it, shall be thrown open, and the water, be proceeding to discharge itself at that end of the pipe. This discharged water will frequently be allowed to run to waste; but where the supply is not superabundant, and where a steam engine, or other machinery, is fixed at a first power station, it will be occasionally run back thither, either through the drains already formed on the railways, to keep them dry, or through other short ones, to be added for this express purpose.

The globe valves of the air-vessels will be also found to be self-acting; and will discharge the water, shot up into these vessels from the propulsion-pipes, very gently into any channels that may be arranged for conducting it away. The two valves, connected with each of the propulsion-receivers, will be found to be also of the same character; being self-acting, through the same simple medium, namely that of the floating globe; and they are arranged with a stirrup, in order to open and close quickly; that is, towards the end of every up or down move of the floating globe on its lever, as it rises and falls with the water. This will be found to be desirable for the proper working of the engine, whenever that machine constitutes the first acting power.

I may here mention, that the man-holes in the air-vessels and propulsion-receivers, which, in the drawing, are represented as opening outwardly, should in practice open inwardly, to render the air-pressure in those vessels available, towards the perfect closing of these man-holes.

The air-valve in the propulsion-pipe, will be only required in case it is found the continuous flexible valve does not always fall to the bottom of the driving-pipe, when the water is drawn off. In that case, this valve, will permit the free discharge of the air, which otherwise would, as the piston advanced, become compressed in the pipe—from its being then closed in front, by

flexible valve—until it might, eventually, even stop the train. But whether this valve will be found in practice, to be requisite or not, its pulley and leverage will be always required; as they also act, through the long connecting rod, which is exhibited as broken off, in the drawing, as reversing machinery for the communication valve. The leverage of this air-valve takes, through its pulley, a rise of eight inches, which it derives from the inclined plane on the driving truck; and it conveys this movement forward—multiplied by the relative proportions of the two arms of its bell-crank—to the communication valve, which—by its action being reversed—it closes with a fall of 14 inches.

The stop-valve, at the further end of a propulsion section, to arrest the progress of the water up that pipe, and turn it into the air-vessel, is to be closed, as it will be observed, by a traddle. This traddle is worked by the front pair of pulley-wheels, carrying the travelling piston; it has a shallow bed or recess in the bottom of the skeleton piping, where it is placed, and into which it falls, when the pair of pulleys throw it down; and, in doing this, throw up the stop-valve. The length of this traddle is three feet six inches; its fall is seven inches, and the lift, carried through the leverage of its bell-cranks upon the stop-valve, is 14 inches; being the full rise of that valve. The traddle will require its seat placing at such a distance in the skeleton, from the stop-valve, as may allow of the piston having wholly passed through, before this traddle begins to act. It has been before explained, that the stop-valve will, by its own gravity, fall, and thus again open the end of the propulsion-pipe—which it is only required to hold closed, while the propulsion-current is rushing up and exhausting itself in the air-vessel—as soon as the tide is turned, as I must beg leave to express it, and the water is drawing off. Now, while I feel the conviction strongly, that the machinery of this valve and the arrangement of its gravity, are good, and fully trustworthy for general purposes; yet I must admit, this valve does not possess that unerring certainty of action, which, I feel assured, attaches to the machinery of the interception valve: I admit too, that all railway machinery should be—

—as the human foresight can make it so—quite unerring in its action.

the machinery of this stop valve to that cha-

arms reaching under the skeleton pipe, and the other, the outside of the rail, in the same line with that of the bell-crank lever of the air-valve. If either the proportion of strength assigned to this lever, or its relative position, is objected to, nothing can be clearer than that a little more metal can be worked up in it; or that, by lengthening its axis till it assume the shape outwardly of a thick short pipe, and by separating its two arms—so that one shall be attached to each end of that axis—any degree of strength, and strict engineering accuracy of arrangement, can be given to this precautionary machinery; the difference being only, that it will occasion a little extra cost, but not much; and, probably, without occasion.

The mode of passing a train from one railway to another, at the junctions, and from one line of rails to another, at the crossings, will require a little explanation; and it will be the more easily given, as the same principle is in operation on both occasions.

The skeleton piping will afford to the hydraulic system great facilities at such places, which will always require to be passed over on a section of that description, where the propulsive water never comes; and the laying down and proportioning the propulsion and skeleton piping, on a railway—by small additions to, or subtractions from, the respective lengths which any given

anywise prescribe for these pipes—so that a section of much more than the average length shall terminate in a running, or immediately beyond it, could never be lost sight of by an engineer. It will require a considerable section of line, beyond the last propulsion-pipe, to allow the impetus, then in the train, to die away, and the speed to be reduced to that, which is usually esteemed safe and proper; particularly at the short runnings, adjoining stations. Sections of skeleton, to terminate at, or near such accidents should be at least 300 yards in length, except where an incline is interposed, of sufficient gradient, naturally to reduce the speed of an approaching train.

When two lines of rails meet, at junctions, crossings, or sidings, a train in the locomotive system, is enabled, by the proper adjustment of the switches, to pass on to either; but this requires a man being constantly stationed on the spot, to work these switches, or points. This individual would be a very useful person in an hydraulic line, as not only the switches would require fixing—which employment occupies usually but a very small portion of his time—but also the junctions of the wire rope, which rope, as it is to extend along each section of skeleton, must evidently join, where there is a junction of pipes and rails. These junctions of rope are easily to be effected. At the end of a short portion of the rope, at the junction, make a loop, by easily (against friction, by having previously wrapped the rope with a strong raw wire strand: at the end of the other portion of the rope, attach a strong narrow hook, shaped nearly like a fish-tail. This is then to be bent down till it nearly meets the loop, and then, affording sufficient opening for detaching it from the loop, at the previously mentioned portion of the rope. Now, as the rope is to be supposed, this rope extends along the skeleton, till it reaches the crossing. Let it be also supposed that, at the crossing, for here dividing the rope. In that case, the man who has to do this, must be provided with a strong instrument, shaped like a pair of the largest garden shears; but which, at the end of each of the shorter arms of this double lever, must possess two fingers, or bent fangs, to take the wire rope between them, and so as to clasp each end of it, where the loop and the hook are. With this instrument, the

rope a little nearer together, which would loose it at the junction ; and who then would be enabled, with much facility, to detach the hook from the loop. Now, instead of *one* such hook, let us suppose there are two attached to the loop ; that is, the one we have already supposed as belonging to the straight line of rails, and another, which we must now imagine as terminating the end of the wire rope, belonging to the skeleton pipe of the crossing, and here joining that which we have been previously considering. The man here in charge of the line, would merely have to detach the loop of that part of the rope, which belonged to that branch of the line, for which he was about to set the switches for the train not to run on, and his work would be done—or rather, nearly done ; for the detached portion of the rope would require to be kept in a sufficient, moderate state of tension, for the convenience of afterwards attaching it again. This would be immediately accomplished, by affixing it to one end of a moveable stout double hook or S, the other end of which, would be temporarily held in any proper opening, cut into the skeleton-pipe for that purpose : or a moveable bracket might be easily contrived to answer the same purpose as this double hook.

In the previous remarks, on joining the wire ropes, it must be clearly understood, that, the loop and hook must not be too large together, to pass with the greatest ease, through the small archway, rising out of the guide-neck of the travelling piston. As iron is the only material to be used, which combines great tenacity with smallness in bulk, this will be arranged without any difficulty.

There is one point, at which the nice adjusting of the wire rope, between tension and laxity, may require practical experience for its perfect arrangement ; and that is, at the short slidings and crossings which are frequently to be met with, at the stations, particularly the larger ones. The rope in such cases, will not lie stretched along the middle of the skeleton pipe, as it ought to do, for its being taken up with perfect facility, by the guide-neck of the piston ; on the contrary, it will lie along the bottom, inclined a trifle from the centre, and bending a little towards that side of the curve next the inside of the curve. But, as at all such places the tension is low, there will be little or no difficulty to be overcome, and will be only necessary, as above intimated,

THE HYDRAULIC RAILWAY.

...the rope to the circumstances of the case. Easing it
...than would be desirable for the higher speeds,
...required. As regards the curves, which occur
...the lines, where the higher speeds are used,
...very wide sweeps as generally to be imper-
...unless it trace them into the distance. The
...wire rope, therefore from the middle of the
...pipe, over an extent—so very small,
...the curve—as that of only 150 yards,
...as nothing; and the very slight side
...occur, in the wire rope sliding up the guide-
...archway on the piston, would be fully
...always having a tendency to draw the
...middle of the rails, and not leaving
...on the outside of the curve, as
...occasions much friction, with a

...water would not answer for propul-
...but if impregnated with salt, and
...never congeal by any fall of temper-
...From this no material expense
...be run back again to the power
...water would at other seasons;
...of drains. From these
...over and over again, with small
...while the frost lasted. A weak
...the congealing power of any
...requisite, fully to saturate the
...material, since the duty
...article. The wise policy,
...restored the natural order of
...which is not only one of
...and several of the arts, but
...After becoming the
...which extensive trades have
...improbable it may extend its
...successfully aid hydraulic rail-
...locomotion is thrown
...if not

the severity of the water. Thus, when the driving-wheels of a locomotive engine cannot bite the rail, and whirl round, with the greatest rapidity, without advancing, the hydraulic system—assisted, instead of being retarded, by the hard ice on the rails, which will give a finer surface—will, with brine in its pipes, be enabled to preserve as much regularity in the time of the arrival of its trains and mails, as during the finest weather. In short, the hydraulic system is not likely to know anything of the seasons; it will not be affected in its operations by them.


justice, they ought not; for if an invention—particularly, if of magnitude—becomes successful, it is not to the patentee, but to the public usually, that the lion's share of the advantage falls.

I have, in a previous part of the pamphlet, proposed, that each first-power-station shall work both lines of rails, over an extent of railway, two miles and three-eighths in length. I have also proposed to use steam wherever water power is not to be found; and, I have intimated that on many lines, I should find it necessary, frequently to have recourse to steam. I shall now, under these conditions, proceed with my calculation of the first cost of laying down, on $2\frac{3}{8}$ miles of railway, the whole of the hydraulic machinery, necessary for working that distance. I shall also, to be on the safe side, assume that such part of any given railway, must be worked by a steam engine. Wherever a locality occurred, which was favourable for a supply of water, the difference between the expense of a steam engine, and that of the piping to bring down the vertical column of water, or of hydraulic machinery, if the head of water had not an elevation of 214 feet, would be easily estimated; and that, according to the circumstances of each particular case. In like manner, nothing will be more simple, if it should be desired, than to ascertain the first cost of any part of the apparatus, enumerated in the following calculation, for one mile of railway. It will be only requisite to take $\frac{1}{16}$ of the sum charged against it.

Calculation of the first cost of establishing hydraulic propulsion over $2\frac{3}{4}$ miles of railway.

Steam Engine, of Cornish construction of 50 horse power, with boilers complete, at £23 per horse.....	£1150	0	0
Engine house, with foundations and chimney, complete	350	0	0
Propulsion-piping, for 38 sections, of 70 yards each (including both lines of rails) of twelve-inch bore, and one inch in thickness, with girths and holdfasts placed every four feet; say gross weight per yard 4 cwt. 2 qrs. 20 lbs., at 7s. per cwt.; then $38 \times 70 \times 4.2.20 \times 7s. =$	4352	5	0
Branch-connecting pipes from first-power-stations and propulsion-receivers for the above; say average, for both lines of rails, $\frac{1}{4}$ the first cost of the above	622	0	0
Skeleton-piping (half-piping, with longitudinal openings along its sides) for 38 sections of 150 yards each, for the pulley wheels of the travelling piston to run upon; say $\frac{5}{8}$ in thickness, and of gross weight of 1 cwt. 2 qrs. 0 lbs. per yard, complete; then $38 \times 50 \times 1.2.0 \times 7s. =$	2992	10	0
Propulsion-receivers feed-pipes of seven inches bore, and $\frac{3}{4}$ inches in thickness, for $2\frac{1}{4}$ miles (3,960 yards) $\frac{1}{4}$ of a mile in each first power division of a railway (<i>i. e.</i> the space between one division and another) not requiring this piping. This piping complete will weight 1 cwt. 2 qrs. 17 lbs. per yard; then $3960 \times 1.2.17 \times 7s. =$	2289	7	6
Two travelling pistons with guide-necks, of the best wrought iron, together, 8 cwt. 0 qrs. 0 lbs. at £3. 10s. per cwt.	28	0	0
Two pairs of springs, with power-connection-plates and iron straps or shackles, for connecting the above named pistons with driving trucks. (N.B. Driving trucks are not charged in this estimate, as they carry loads, the same as other trucks)	50	0	0
Two Travelling inclines, for two driving trucks, with stays to slot and levers, weight of each complete, 2 cwt. 2 qrs. 0 lb., say 5 cwt. 0 qrs. 0 lb., at £2. 10s. per cwt.	12	10	0
Two piston valves, with motion rods.	16	0	0
Valve machinery for thirty-eight sections of propulsion-pipe; say for each section, machinery £46., and four valves and boxes £24., therefore $70 \times 38 \dots$	2660	0	0
Continuous flexible valve for each section of propulsion-pipe, £10. 10s.; and wire rope for each section of skeleton £2. 10., therefore $10 \times 10 + 2 \times 10 \times 38 \dots$	494	0	0
Jointing and fixing pipes, and putting down machinery per mile, £240; therefore, for $2\frac{3}{4}$ miles	570	0	0

Carried forward.....£15,586 12



valves, and air vessels, and the difference between the value of the propulsion pipe, and continuous valve, and that of the skeleton pipe and wire rope, on so much of each line of railway, in every mile, as this alteration would apply to, from the inclines being favourable, and the trains, with the aid of the momentum in them, being able to descend without any decrease in speed.—(N.B. Over such portions of the rails, the skeleton piping and wire rope, only would be wanted.)—On Railways already established, this deduction would not often be very large in amount. On Railways, to be established for Hydraulic propulsion, it would be very considerable, as the distance to which it would apply, probably would frequently be equal to one third of the cost of the whole line.

Deduct for diminished weight of rails, in consequence of locomotive engines and tenders—which comprise an immense load within a contracted length of rail—being dispensed with, and the weight of the trains being spread evenly over a sufficient length of the line. This will probably effect a saving of, from £400. to £500. per mile, as in the atmospheric system.

Deduct, for diminished height of tunnels, in consequence of their present extra elevation to allow the chimney of the locomotives to pass, not being required: deduct also, for diminished height of bridges over the line, and adjoining earthworks.

rather surprised the guards, seated on the tops of the coaches, on the locomotive system, have not something of this sort to convey their communications, and orders to the drivers on the engines.

I mentioned in an early part of this treatise, that the circumstances of the case, seemed to require that, before concluding this pamphlet, I should bring hydraulic propulsion into a state of fair comparison with the atmospheric railway, as the two systems were, by many individuals supposed to be analogous in character;* and that whatever position one might stand in before the public, would be equally that, due to the other. I will dispose of this subject in a few words: the atmospheric system proposes to work under half an atmosphere; the hydraulic, under six atmospheres; the atmospheric proposes to lay a driving-pipe along the whole section of the line, of, from 15 to 18 inches in diameter; the hydraulic requires a pipe of 12 inches diameter over one-third of the whole line, aided by light additional skeleton and feed-pipes; the first has to incur the heavy expense of boring the pipe; the second has not; the first appears, from the power of the engine, which is to work the Dalky-extension of the Dublin and Kingstown Railways, to require fully four times the steam power of the second; but this should not be insisted upon, as

* I must here again refer to note B.

everything material in the arrangement of the atmospheric system. To that public report, is appended an admirable letter from Mr. Pim ; to which, indeed, the report may, I believe, be considered as the observations of the Government Agents in reply. It will remain for my readers to decide whether I am correct, when I state, I imagine that from Mr. Pim's letter, if allowance were made for the comparative state of the forces and peculiar characteristics of my system, several excellent arguments might be adduced in favour of hydraulic propulsion.

In concluding these sheets, I feel I ought to express my regret at their hurried, and, therefore, imperfect state ; but, however imperfectly I may have accomplished my undertaking, I hope I have done enough to leave on the minds of a large portion of my readers, the strongest impression, that hydraulic propulsion will prove :

1st.—Of extraordinary power.

2nd.—Economical, as a working railway.

3rd.—Cheap, for the establishment of new railways on its principle.

4th.—Essentially safe ; and secure against collisions of trains, running off the line, and *fire*.

5th.—Regular in time of arrival, and in always maintaining a uniform and high speed.

7th.—Highly conducive, as the above particulars imply, to public and individual advantage, and to general convenience.

E S.


PAGE 13.

th the inquirer into the principles of
s being of the highest authority, and
mulæ for the right base and construc-
clusions, is Tredgold's "Tracts on
ns three tracts, which are edited by
lded some notes. The first tract is
ater and Wind to turn Mills, &c.;" the
periments on the Motion of Fluids;"
ummary of Practical Hydraulics, chiefly

erence to the subject of this pamphlet.
aks thus of Venturè's :—"In judgment,
Smeaton, as he is superior to him in
, it will be found he sometimes builds
periments." But on the subject of the
vations will be found, in the preface to

ng's Summary of Hydraulics, we have
ie advertisement which precedes it; and
motion of waters in rivers, the inclination
ity of water in pipes, are there given in
than in any other work extant; and may
tions relative to the right of water in arbi-
culations for new water works."


st alluded to, as appearing in his advertise-
Young's tract, is as follows :—
il engineer, much of his success depends on



There is an important chapter, and one of the longest, in Dr. Young's tract, with a very material extended note on it from Tredgold, from the formulæ in which I take my data, in this pamphlet, for establishing, and proving the beneficial results to accrue from applying hydraulic propulsion as the driving agent on railways. But while the article on "the motion of water in pipes," (chapter 13), is fully sufficient, clear, and satisfactory, for all practical purposes—or if it err at all, it is, as I think I shall be able to show, on the safe side—I cannot but regret that in Dr. Young's work of twenty-four chapters, but one should be devoted to that important subject; comprising, as it does, in it, the leading principle, which governs the supply of all waterworks; and which, very probably, also contains within it, much power available to other important purposes, without considering how far its influence may affect and confirm to the principle of railway hydraulic propulsion. Dr. Young's tract, however, as intimated in the text, is not singular in this respect, particularly when the working out of this principle on a large scale, is in question; indeed, if the work alluded to be singular at all, it is in bestowing more attention to this subject, than is to be met with in some other writings. But I shall have to recur to this; and then I think I shall be able to establish, at least a strong probability, that the formulæ or rule—on which on the present occasion, and in default of better data, I am ready to base the claim of my invention on public notice—will be deficient in amount of result.


now be done, subject to a less unfavourable construction, than might have been the case some months back ; as the Dublin and Kingston Railway Company have resolved to extend their line about a mile and three-quarters (to Dalkey) on the atmospheric principle. The ultimate position, therefore, which the atmospheric railway must shortly assume in public estimation, can no longer be affected by the remarks of any writer whatever on its subject, whether favourable or otherwise : its character and capabilities will be determined by the results of the trial, to which its powers are now being practicably submitted by the Dublin and Kingston Railway Company. At the same time, any remarks I may have to offer, in the way of bringing into fair contrast, the principal characteristics of my own, with those of this very ingenious and skilful invention, shall certainly be as brief as the subject will admit of.

Extract.—January, 25th, 1842.—“ Whatever plan you adopt, it will be highly advisable, in drawing up your description, to assume that little, if anything, is known of the nature of your patent. It may even be necessary to ensure its being perfectly intelligible—and it is only by making it so that you can expect it to be appreciated as it deserves—to explain any principle of hydrostatics, which is not at once obvious, or at least, very generally known. This is the more necessary, as an opinion has gone forth that the pneumatic railway is a failure ; and with those who know nothing more of yours than the name, it is apt to be considered an analogous attempt. I do not say this without reason. *



numbers, already mentioned ; and must allow that if two heavy bodies A and B, be let fall one second after another, the first would get ahead of the other ; nor would they keep at an equal distance during their descent. For, if at the end of one second after A is let go, B should be delivered, the first would be proceeding at the rate of 3, while the other is getting on but at the rate of 1. During the third second, A will be urged on with the force of 5, while B can have obtained the celerity but of 3. So that, if at the end of the first second, they were but a rod asunder, at the end of the second, they would be three rods apart, five at the end of the third, seven at the end of the fourth, and so forward, progressively. Yet it ought here to be considered, that the water in our perpendicular pipe, does not run into and out of it successively, and by starts, but evenly and continually. And though by the acceleration of falling bodies, their velocity does increase, on which account the water, in its progress through the pipe, if the resistance of the air, and every other impediment was away, might be allowed to be a small matter rarified ; yet as the particles of water contained in the descending pillar set forward one after another in spaces of time infinitely short, and, being tenacious, adhere pretty well together, they appear, as to the sense, to make an even stream, and full in every part. It is, therefore, impossible that, so long as there is water in the vessel for a supply, such pipe should become void of water, nor is the objec-

distinguishing characteristics of a modern railway. But while it can afford both power and velocity to railways at a proportional expense, it can also offer to colliery tramways, or to stone or iron tramways, to be laid on high roads, or to branch railways, where a moderate speed would be considered sufficient, as well as to canals and rivers, where haulage is employed—very great capabilities of transit, at speeds varying from six to ten or twelve miles an hour; and this, too, at a very moderate first outlay. The agency of air-vessels, propulsion-receivers, propulsion-feed-pipes, &c., is requisite on the railway system, to obtain high speeds without great retardation; but when a great velocity was not required, these media might—with the exception of one propulsion receiver for about every two or three miles, to reverse the action of the propulsive power—be dispensed with, their first cost might be saved, and a fair moderate speed obtained from the hydraulic current being discharged directly upon extensive lengths of driving pipes, and without any intermediate agency whatever. The propulsion-pipe also might be much reduced in diameter where a very great speed or tractive power would never be required; and it will, therefore, be evident, that the amount of first power might equally be lowered. Such things would make a very great alteration in the first cost. Besides, water-power would be more frequently obtained in the hilly districts, through which roads, tramways, canals, and rivers



without intermediate agency, on each side of a first power station. The regularity in the operation of the system, would prevent many stoppages and much confusion, and probably allow of a larger traffic being passed along a canal than is practicable on the present system. It would take the boats admirably through tunnels ; in which, when there was no towing path, the propulsion-pipe might be tied along the top of the roof or arch, with its continuous cleft along the bottom, instead of the top of the pipe ; other parts of its machinery being also reversed, in a manner that will be sufficiently obvious. The vessels would require attaching by a towing line, to the power-connexion plate. The canal would be worked in each direction alternately, like a railway of a single line ; and some other minor and simple arrangements, on the score of adaptation, would require attention.

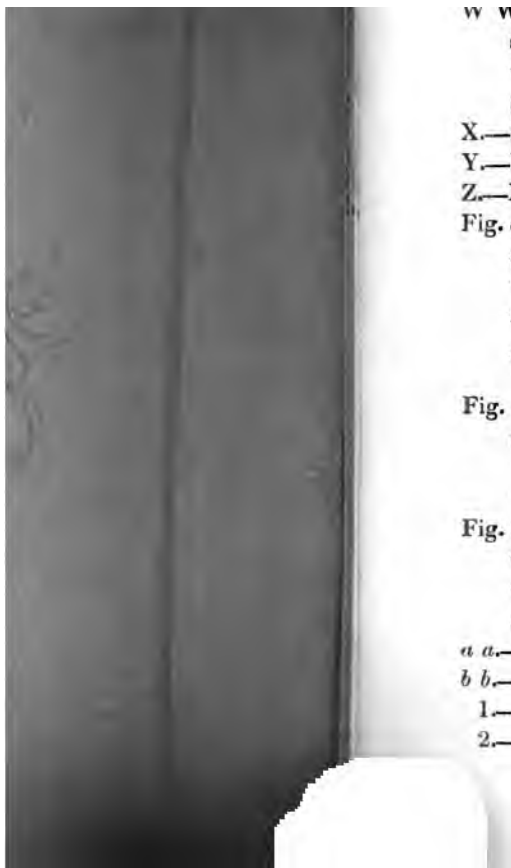
in a pipe, and to carry the power so derived, by a flat iron plate, rising out of the crown of the piston, through a longitudinal continuous cleft in the pipe, and then to apply this power, when thus brought out of the pipe, upon a train upon a railway;—the continuous cleft to be filled up by the peculiar working adjustment of a continuous flexible valve, just as the piston passes; and so as to close and make the pipe water-tight, which is behind it, and filled with water. The hydrostatic force of water in pipes, under adequate pressure, is very great; and were there no retarding influence to its free passage up pipes, its application upon machinery would be remarkably simple. It happens, however, that, at high speeds particularly, the friction or retardation in the water increases, with the length of the pipe, very materially. Hence, it becomes necessary to keep each section of the “propulsion-pipe” of a moderate length, to adopt its final velocity as the driving speed, and to run the trains, by the momentum or impetus, which has been thrown into them, from this source of power in the propulsion-pipe, a certain distance further over a section of “skeleton-pipe,” without more power being expended on, or rather being made to follow them uselessly, when they are full of driving force. This arrangement will render it necessary for the water, under pressure, being conveyed *slowly*, during the intervals between the passing of the trains by a small additional pipe, to “propulsion-receivers” (or store-receptacles of hydraulic power), to be placed in positions adjoining the sections of propulsion-pipe (as they will occur at regular intervals along

the line,) from which the water may be again discharged, as the trains go by, into those sections of pipe. Thus, this system of propulsion is founded on those laws of hydrostatics, which give power over a limited extent, at a great velocity, and power over almost any extent, at a proportional slowness of speed: and it is from the mutual co-operation, or rather from the reciprocal action of these two laws, in the manner intimated, that railway hydraulic propulsion is enabled to promise that amount of beneficial result, which, in this pamphlet is claimed for it; the authorities for which, are brought forward, and the necessary calculations given.

FRONTISPIECE.—It has been intimated to me, that, as the drawing shows nothing but the machinery of the system, it may, to some, convey the idea, that hydraulic propulsion appears to be replete with it. I have, therefore, thought it well to exhibit a portion of a railway, ninety-two yards in length, as it would appear to the eye, when a train was passing. This extent of line, I have obtained in the frontispiece, on a scale of $\frac{1}{4}$ an inch to the yard, by showing it in two lengths, one below the other. This enables me to exhibit, first, a small portion of skeleton piping, then a “first power station,” acting immediately from the pressure of a vertical column of water, brought down by piping, from high ground contiguous to the railway: after that, this arrangement enables me, at the commencement of a section of propulsion-pipe, to show the first motion of the machinery, or, at least, so much of it as can appear to the eye; the remainder of it, being equally diminutive, if thus brought into juxtaposition with all the great objects about it; I can then exhibit a train of carriages, headed by the driving truck; and I am enabled to complete the seventy yards of propulsion piping, by showing, the reversing machinery and air vessel in their proper, relative positions: after which, this railway sketch terminates with a few yards of the next section of skeleton pipe. Now, to assist in conveying, from this little frontispiece, a just idea of the proportions of the system, it is proper to state that, though only one line of rails is here exhibited in working order; yet a large portion of the most important part of the system may be rendered common to both lines of rails, just as well as confining it to one only. Another also should never be lost sight of; namely, that the machinery in the frontispiece, is shown as working 92 yards of railway, *be all that would be required for two hundred and twenty* the rest of that distance being skeleton pipe, with no working whatever upon it.

REFERENCES TO FIGURES AND LETTERS, &c.

- A A.—Skeleton pipe.
- B B B.—Vertical column pipe, with its curves, to fall into propulsion-pipe.
- C.—Junction of vertical column, and propulsion-pipes.
- D D D.—Propulsion piping, one inch in thickness.
- E.—Water thrown into propulsion-pipe, behind the travelling piston, by the partial lifting of the communication valve.
- F.—Communication valve.
- G.—Interception valve, closed against its seat, being thrown up by the first rush of propulsion water, through the junction C. It will be held upon its seat till the pressure of the water is cut off.
- H.—Air valve (Fig. 2) half-open, and only requisite when *t t* are required to act.
- J.—Stop valve to arrest the progress of the water when the piston has passed forward, out of the propulsion-pipe.
- K.—Discharge spout, which will frequently require to be placed at the other end of the propulsion-pipe, where it joins the skeleton ; *i. e.* when the inclination of the piping is in that direction, and when the water must consequently be drawn off at that end, and close to the vertical column pipe.
- L L.—Travelling piston, with its guide-neck before it.
- M M M.—Pulley wheels to carry and direct the piston and guide-neck. The first pulley, near the snout of the guide-neck, is fixed vertically (there will be a second wheel on the same axis making a pair ; the continuous valve, passing along the space, between this pair.) The second pulley wheel is fixed horizontally, and the third, behind the piston, vertically, thus in every direction guiding it clear of the sides of the pipe.
- N.—Axle of the driving truck (Fig. 7.)
- O O O.—Continuous flexible valve.
- P P.—Wire rope to keep up the connection along skeleton piping, with continuous valve in driving (propulsion) piping.



W.—Curved branch pipe from vertical column pipe, or first-power station, or propulsion receivers (broken off) to convey propulsion water to driving pipe, belonging to the other line of rails (namely that line not shown.)

X.—Springs of the driving truck, shown in back elevation, (Fig. 7.)

Y.—Brass axle boxes.

Z.—Buffers in front of the truck, the back ones being removed.

Fig. 5.—Transverse section of propulsion-pipe, continuous valve, and guide-neck of piston, showing the iron belt round the guide-neck, which is to connect the arms of the piston valve. This belt is in fact, the piston valve arm divided, in order to carry it round the guide-neck, and then pass it out of the pipe, and for the driver to control it on the truck.

Fig. 6.—Transverse section of continuous flexible valve, guide-neck, and propulsion-pipe, at the girths round the pipe, and hold-fasts; which latter are to fasten down to the blocks or sleepers. (Drawn to a larger scale, as shown.)

Fig. 8.—Sketch (without reference to proportions, for want of space) to bring before the eye, the arrangement of the propulsion, skeleton, and receivers' feed-piping, for working both lines of rails. (See at No. 61, and the following.)

a a.—Communication valve box.

b b.—Ditto ditto rod, and its connecting arm.

1.—Ditto ditto valve lever.

2.—Ditto ditto load arm.

at Fig. 1.

- 8 8.—Second pair of reciprocating levers, the top one of which is shown dotted through at Fig. 1., and shown, looking down upon it from above, at Fig. 4. The bottom lever of this pair is exactly covered by 13, (on which, however, its own number (8) is shown,) opposite to which, it is placed, on the other side of the rails.
- 9.—Shaft to carry action of reciprocating levers under the rails, from the far to the near side of the line, in order to keep the machinery out of the way of the passengers.
- 10.—Lever conveying, from its pulley, through shaft 9, &c., first move to communication valve, which it opens about one-third.
- 11.—Rod to 10.
- 12.—Pulley to ditto.
- g g.*—Pillar for above leverage.
- 13.—Lever to carry motion forward to air valve, H, Fig. 2.
- 14.—Connecting for above purpose.
- 15.—Lower arm of bell-crank of air valve, to reciprocate in due relative proportions, for opening and closing action 13.
- 16.—Upper arm of above bell-crank to communicate closing action through leverage, previously described, to communication valve.
- 17.—Rod to the above.
- 18.—Pulley for ditto to act, when the incline on the driving truck lifts it, in passing.
- h.*—Pillar for above leverage, rod, and pulley.

the connecting rods, &c., to open the piston valve, and to close it again.

n n.—Incline or driving truck to throw up pulleys 12 and 18, as the truck passes.

p p p.—Bent, double forked lever, with its long axis, to slot the incline back close to the truck, when the driver wishes to stop the train. This it will cause, by its being thus placed out of reach of the pulley, when the communication valve to throw water into the propulsion-pipe will not be acted upon.

r r.—Rod and handles, to work the above.

s s s s.—Wheels of driving truck.

u u.—Strong springs carrying power connection-plate, and allowing a little play, in case of any unevenness in the rails.

t t.—Two pulleys or friction wheels to put continuous valve down, in case it ever sticks in continuous cleft, so as to enable it to enter *k* freely.

w w.—Supports from driving truck for above pulleys.

26.—Traddle to close stop-valve, acted upon by front pair of pulley wheels *M* of travelling piston *L*.

27.—Bell crank, carrying the action of the traddle forward, by the aid of the small connecting rod between them.

28.—Longer connecting rod between the two bell-cranks.

29.—Second bell-crank to apply action of traddle upon stop valve.

30.—Supports from the skeleton pipe, to the two bell-cranks.

31.—Stop valve rod.

at a proper tension.

z.—The above load.

39.—Orifice from propulsion-pipe into connecting pipe, to air vessel.

40.—Above connecting pipe.

41.—Clack valve, opening inwards, in the air vessel, to prevent the recoil of the water into propulsion-pipes.

42.—Air globe (self-acting) to lift small discharge valve, 43, when sufficient water has passed into the air vessel to float the globe. The water, so discharged, is to be carried off in a proper drain, for use again, or to run to waste, as occasion may dictate.

43.—Discharge valve above mentioned.

44.—Manhole. This number also refers to the manhole in the propulsion receiver.

45.—Junction of receivers feed-pipe U, and of curved branch W, with vertical column pipe.

46.—Chairs.

47.—One line of rails.

48.—Sleepers.

49.—Blocks.

50.—Holdfasts to bolt down to blocks or chairs.

Fig. 3.—(Drawn to half scale.)

51.—Connecting pipe to propulsion-pipes, of the same character as the curve at B. The other piping in this figure is explained by the the letters on it (being the same as on the other figures), and is shown without valves, &c., which leaves the propulsion-pipe, and its arrangement, open to view.

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- 52.—Air globe on its lever or guide-arm ; to be of sufficient load to throw open valve 55, against a preponderating pressure.
- 53.—Upright rod, down to valve at 55.
- 54.—Stirrup, through which guide-arm of 52 moves, so as to establish action of valve only just before the full charge of propulsion water is thrown from the receiver into the driving pipes, and so as to close the valve again quickly, just as the receiver is replenished with another charge.
- 55.—Feed valve between receiver and its feed-pipe U, opening downwards.
- 56.—Connecting rod from 55 to 57.
- 57.—Small interception valve and box, to close when 55 is open, and to open when it is closed ; thus turning the water into this receiver or allowing it to pass on to the next, as required.
- 58.—(Figs. 1 & 7.) Partitions in driving truck, inside, to box off so much of the wheels as would be otherwise there exposed.
- 59.—Guard's box, in that division of the truck which is divided off for him and the driver.
- 60.—Seats for the guard and driver.
- Fig. 8.—(*Drawn without any proportions, as already explained.*)
- 61.—Vertical column pipe.
- 62.—Propulsion receivers.
- 63.—Ditto piping, on one line of rails, to represent 70 yards on each curved line.
- 64.—Skeleton piping, to represent 150 yards in each small dotted section shown of it.
- 65.—Propulsion piping, representing (as at 63,) a section of 70 yards, in each branch, to reverse direction of driving power (as indicated at W in preceding figures) for the other line of rails ; say, for that, not exhibited in this drawing.
- 66.—The two lines of rails.
- 67.—Propulsion receiver's feed pipe.

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